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MOORPARK-MOTTLE: A VIRUS DISEASE OF APRICOTS IN NEW ZEALAND

By E. E. CHAMBERLAIN, Plant Diseases Division, J. D. ATKINSON, Fruit Research Station, and J. A. HUNTER, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(Received for publication, 21 October 1953)

Summary

A virus disease causing mottling of leaves and distortion of fruit has been found in five Moorpark apricot trees in a Central Otago orchard.

This disease, not previously recorded, has been tentatively named moorpark-mottle. It has been experimentally transmitted to Moorpark and seedling apricot, Paragon and seedling peach, and to cherry plum.

Eradication is being attempted.

INTRODUCTION

Recent investigations of fruit tree diseases have indicated that a number of viruses occur on stone fruits in New Zealand. An account of one of these, plum-mosaic, has been published (Chamberlain *et al.*, 1951).

Unusual mottling of foliage was observed on a Moorpark apricot tree in a Central Otago orchard in January 1950. Subsequent examination of this block, comprising 89 Moorpark trees, showed that four other trees displayed similar symptoms. The disease has not been observed elsewhere in the Dominion.

Budwood secured from infected trees was used to carry out transmission and host-range trials at the Owairaka research area. Results of these trials, together with a description of field symptoms as they occur in Central Otago are given in this paper.

SYMPTOMS

Foliage symptoms on naturally infected Moorpark apricot trees consist of light green areas of varying shape and size (Fig. 1). These chlorotic areas may be scattered irregularly over the surface, grouped round margins or towards tips of the leaves, or on a few leaves may form irregular patterns (Fig. 1). They are more pronounced on upper

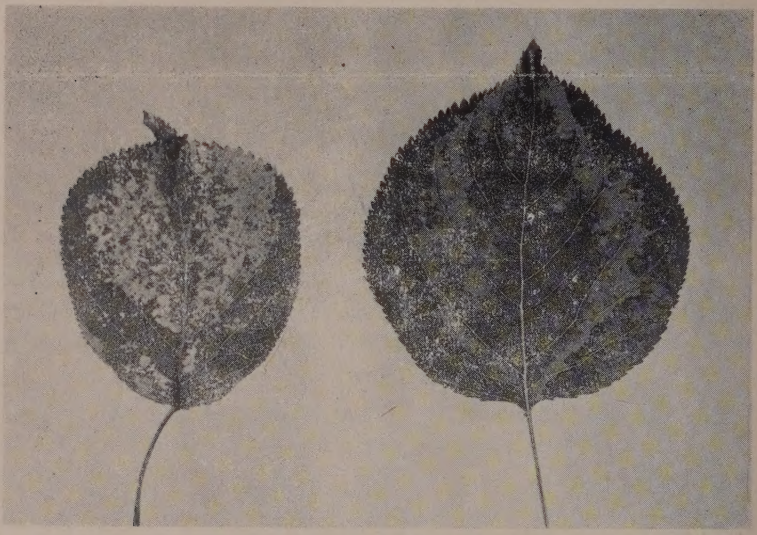

FIG. 1.—Moorpark-mottle on apricot: leaves from naturally infected Moorpark apricot showing mottling. Note irregular pattern on leaf at right. X 4/5.

Photo: S. A. Rumsey

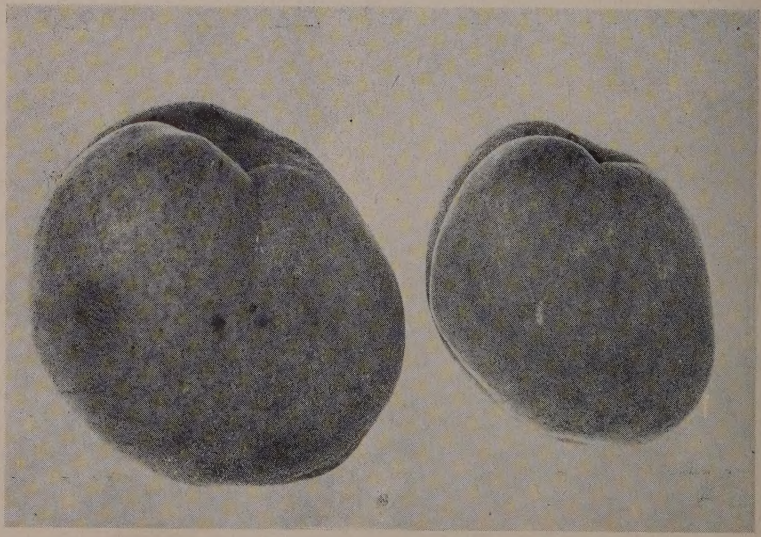

FIG. 2.—Moorpark-mottle on apricot: fruits from naturally infected Moorpark apricot showing distortion. Nat. size.

Photo: S. A. Rumsey

leaf surfaces. During October and November symptoms are indistinct, and do not become conspicuous until late December or early January. Symptoms are general throughout infected trees, but have not been observed on small immature leaves.

Fruits from infected trees are misshapen, growth being restricted on that portion of the fruit opposite the suture. Depressions occur on either side of the fruit near the stem cavity, and give infected fruits the appearance of having been pinched (Fig. 2). Diseased fruits are smaller than normal, and, according to the grower are tough and leathery, and mature approximately a week later than fruits on healthy trees. Fruit symptoms first appear about mid-January, and become more pronounced as fruits mature.

Growth of trees does not appear to be affected.

TRANSMISSION TO APRICOT

In February 1951, twenty-four seedling apricot stocks were double-budded with buds from both infected and healthy Moorpark apricot trees, while a further 24 stocks were budded with healthy Moorpark only. Under Auckland conditions, if budding is deferred until February when growth may have temporarily ceased owing to high temperatures and/or dry soil conditions, difficulty is often experienced in securing a satisfactory bud-take on apricot stocks. Thus in the present trials on the 24 double-budded trees, scions developed on four stocks only, a healthy scion on one stock, an infected scion on one stock, and both healthy and infected scions on two stocks. On check trees only one healthy scion grew.

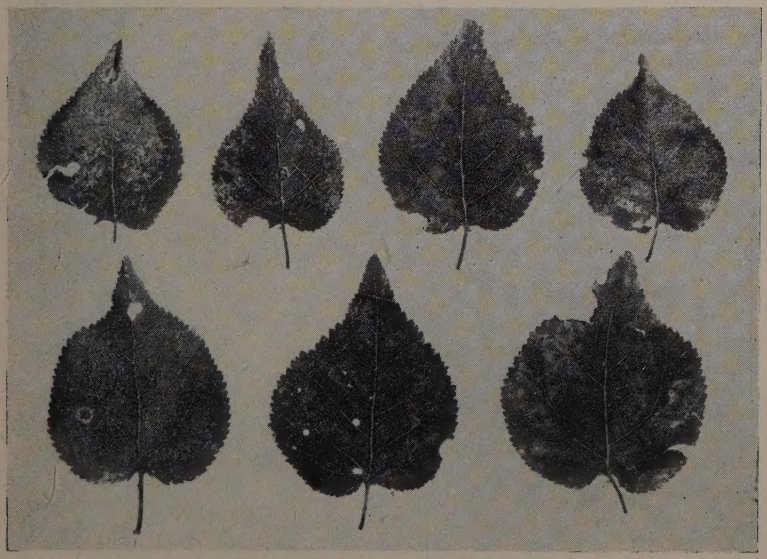

FIG. 3.—Moorpark-mottle on apricot: Leaves from experimentally infected apricot seedlings showing chlorotic mottling, ring-spotting, and vein-banding. X3/4.

Photo: J. W. Endt.

On double-budded stocks, during the season following budding, symptoms appeared on two of the three infected scions, and on one of the three originally healthy scions. No symptoms appeared on any of the stocks. In the second season after budding all three infected scions and all three originally healthy scions showed symptoms. Of the 23 stocks showing growth, ten developed symptoms.

On both infected and originally healthy Moorpark scions symptoms were similar to those present on infected trees in Central Otago, but on stocks symptoms were variable. In some cases they were similar to those on Moorpark, but in others they consisted of chlorotic ring-spots, indistinct vein-banding, or interveinal chlorosis (Fig. 3). No symptoms appeared on check trees either on the stocks or on the single Moorpark scion.

TRANSMISSION TO CHERRY PLUM

In March 1950, nine healthy cherry plum stocks were worked with buds from moorpark-mottle infected apricot trees, four buds being inserted in each stock. Fifteen scions developed on seven stocks.

During the season following budding symptoms were observed on two only of the 15 scions. Chlorotic foliage symptoms appeared on three cherry plum stocks.

Stocks were not cut back, with the result that by the second season after budding ten scions had died. The remaining five scions all developed typical symptoms of moorpark-mottle. In the second season seven of the nine stocks showed chlorotic leaf markings. Leaf symptoms on cherry plum stocks consisted of light-green to creamy-white spots, ring-spots or indistinct line patterns (Fig. 4). Growth of stocks was apparently unaffected.

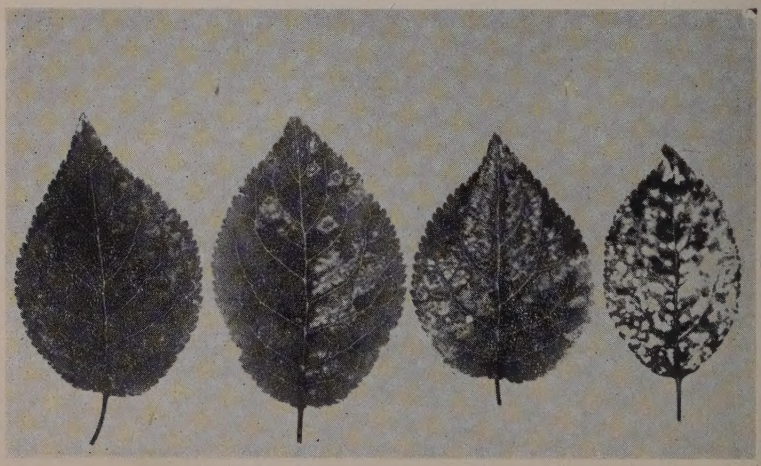

FIG. 4.—Moorpark-mottle on plum: leaves from experimentally infected cherry plum stocks showing chlorotic spots, ring-spots, and indefinite patterns. X 3/4.

Photo: J. W. Endt.

TRANSMISSION TO PEACH

In February 1951, four healthy seedling peach stocks were double budded with moorpark-mottle infected apricot and healthy Paragon peach buds. On two stocks scions failed to develop; consequently, these trees were removed. On the two remaining stocks both buds developed on one, and the apricot bud only on the other.

Typical moorpark-mottle symptoms developed on leaves of one apricot scion in the season following budding. In the second season no symptoms were observed on either scion, possibly because of the premature fall of the basal leaves, on which symptoms usually develop. Stock growth developed on the tree carrying the apricot scion, but not on that carrying both apricot and Paragon peach scions.

In the season following budding, severe symptoms developed both on peach stock and on Paragon peach. Symptoms on leaves of Paragon consisted of red vein banding, ring-spotting and blotching, interveinal chlorosis in which chlorotic areas were often bright yellow, and

FIG. 5.—Moorpark-mottle on peach: leaves from experimentally infected Paragon peach showing interveinal chlorosis, and necrosis with tattering of margins. Leaf from healthy Paragon on left. X 1/2.

Photo: S. A. Rumsey

necrosis of leaf margins (Fig. 5). In many leaves a red zone bordered the inside of necrotic areas, and as leaves aged the necrotic areas broke away, leaving tattered edges. On upper leaves symptoms appeared first as chlorosis of leaf margins which later turned red, and finally became necrosed. The youngest leaves did not show reddening or necrosis, but remained a paler green than normal. The tree was much

FIG. 6.—Moorpark-mottle on peach: leaves from experimentally infected seedling peach showing chlorosis and reddening and necrosis of margins. Leaf from healthy seedling peach on left. X 1/2.

Photo: S. A. Rumsey

stunted, and older leaves fell prematurely, leaving bare stems with tufts of leaves at the tips. Symptoms on the seedling peach stock were similar to those on Paragon except that chlorosis tended to be more general, leaf margins did not become tattered (Fig. 6), and effect on tree size was not so pronounced.

In the second season after budding, the first leaves produced on both seedling peach stock and Paragon scion turned red, developed necrotic spots, and fell prematurely. Leaves on new growth, however, failed to develop symptoms, and by the end of the season, both trees, although still stunted, appeared to be making normal growth.

CONCLUSIONS

Transmission experiments with Moorpark and seedling apricot trees have shown that chlorotic leaf symptoms associated with moorpark-mottle are caused by a transmissible virus. As apricots do not produce fruit in Auckland, and as it was considered unsafe to grow infected trees in an apricot growing area, it has not been possible to demonstrate that fruit distortion is definitely associated with leaf mottling, or that it is transmissible. Since, in the field, fruit symptoms were present on all five trees known to show foliage symptoms, and not on any others, it is reasonable to assume that foliage and fruit symptoms are associated.

Transmission experiments with other hosts indicate that moorpark-mottle is transmissible to peach, producing severe shock symptoms in the year following budding, and to cherry plum, producing a comparatively mild leaf chlorosis. As symptoms produced by this virus do not correspond to any recorded apricot virus, it has tentatively been named moorpark-mottle.

ERADICATION OF MOORPARK-MOTTLE

Since moorpark-mottle appears to be a potentially dangerous stone-fruit disease, and to be of limited distribution, its eradication is being attempted. All five infected trees known to be present in Central Otago have been removed and destroyed. Except for a few trees being kept for further observations, all infected material at Owairaka has likewise been destroyed. Infected trees will be removed as soon as symptoms have developed during the coming season.

ACKNOWLEDGMENTS

The authors wish to acknowledge assistance given by members of the Horticulture Division, Department of Agriculture, who collected and forwarded budwood, assisted in field surveys and arranged destruction of infected trees in Central Otago.

REFERENCE

CHAMBERLAIN, E. E.; ATKINSON, J. D.; HUNTER, J. A., 1951: *N.Z. J. Sci. Tech. A33* (*2*) : 1-16.

APPLE RING SPOT

By J. D. ATKINSON, Fruit Research Station, E. E. CHAMBERLAIN and J. A. HUNTER, Plant Diseases Division, Department of Scientific and Industrial Research

(Received for publication, 16 November 1953)

Summary

Ring-spot, an unrecorded disease of apples, has been known in New Zealand for eighteen years. Symptoms are found only on fruits, where they appear as patches of russetted tissue edged with a smooth dark brown band, and occasionally as partial or complete concentric dark brown rings. Loss is not serious, but the disease is widespread in the variety Granny Smith.

Grafting experiments have shown that symptoms are perpetuated in infected scions, and suggest that the disease is transmitted slowly from infected scions to healthy trees. It is thought that the disease may be caused by a virus.

INTRODUCTION

About the year 1935 Mr. L. W. Tiller* observed an unusual symptom on Granny Smith apples growing at Brightwater, near Nelson. Affected apples showed one or more sets of concentric brown rings on the surface. Apples of the same variety showing similar rings associated with patches of russet were found near Auckland in 1939. In both districts only a few trees were affected. No pathogenic organism was found associated with these peculiar markings. During 1947 and 1948, a number of Granny Smith trees producing apples with similar symptoms were found in several orchards near Auckland. As the disease appeared to be spreading in the important variety Granny Smith an investigation was undertaken. Officers of the Horticulture Division, Department of Agriculture, carried out field surveys that will be reported elsewhere, while the authors attempted to identify the cause of these markings. Although investigations are not yet complete the time is opportune for a progress report.

For some time the disease has been known in New Zealand as Henderson-spot, a name derived from the place where it first caused concern. As this is not descriptive the name ring-spot is proposed.

SYMPTOMS

Symptoms of ring-spot have been found only on apple fruits. Trunks, branches, and leaves of affected trees appear normal, and growth is not visibly affected. First signs of the disease appear in early December when young apples are about 3 cm. in diameter. At this stage faint light brown areas show through the downy covering of small fruit. These markings develop into irregular shaped patches of varying shades of brown, with a rough russetted surface, and a scaly margin. In this form, ring-spot symptoms

* Mr L. W. Tiller was at that time Manager, Appleby Research Orchard, Department of Scientific and Industrial Research.

closely resemble bronze beetle injury, and some types of spray russet. Shortly before harvest a narrow band of smooth dark brown tissue forms round the margin of many spots, and this is regarded as a reliable diagnostic feature (Figs. 1 and 2). After picking, this outer brown strip occasionally continues to develop, but most spots remain unchanged throughout the storage life of affected apples.

A less common but more striking symptom of ring-spot is shown in Figs. 3 and 4. On these apples concentric rings of dark brown tissue are mixed with patches of rough scaly russet. Occasionally rings are almost complete (Fig. 3), but fragmentary rings are more common (Fig. 4). A few apples have been found with sets of concentric rings but no russet patches.

In all cases blemish is confined to the surface, and there is no sign of internal abnormality. Flavour and storage quality are not impaired but appearance is unattractive. Where symptoms are slight apples are saleable in low grades, but fruits showing severe symptoms are rejected. On trees that show marked symptoms, ring-spot reappears year after year, but the percentage of fruit affected varies widely from season to season. Other trees may produce a few affected apples one year and none the next. Distribution of symptoms within the tree is most erratic. All fruits on a branch may be affected, or there may be only a few diseased apples among many apparently sound ones. There is similar variation among apples on a single spur.

INCIDENCE

Ring-spot on Granny Smith apples has been found by officers of the Horticulture Division, in the Auckland, Hastings, and Nelson districts. On severely infected trees up to 50 per cent of the crop has been rejected in some years but, in general, loss is slight. The disease in a mild form is widespread in the districts named, but the potential threat of serious loss has not developed.

Odd fruits of the varieties Cox's Orange, Delicious, and Sturmer showing symptoms similar to ring-spot have been found. Each of these had one or more patches of scaly russet, edged with a smooth dark brown strip, but none showed concentric rings.

EXPERIMENTAL PROCEDURE

Repeated attempts to isolate a pathogen from apples affected with ring-spot gave negative results. Burrell (1940) reported the appearance of concentric rings on Northern Spy apples in the United States of America as a symptom of boron deficiency. Although symptoms of ring-spot in no way resemble boron deficiency as known in New Zealand (Atkinson, 1936), borax was applied at the rate of ½ lb. per tree to 17 affected trees in the spring of 1952. This treatment failed to have any influence on the development of ring-spot symptoms during the following season.

As field evidence suggested that ring-spot was perpetuated in scions taken from affected trees, grafting experiments were under-

Fig. 1.—Russet patches with brown margins beginning to form on a Granny Smith apple infected with ring-spot.

Photo: S. A. Rumsey

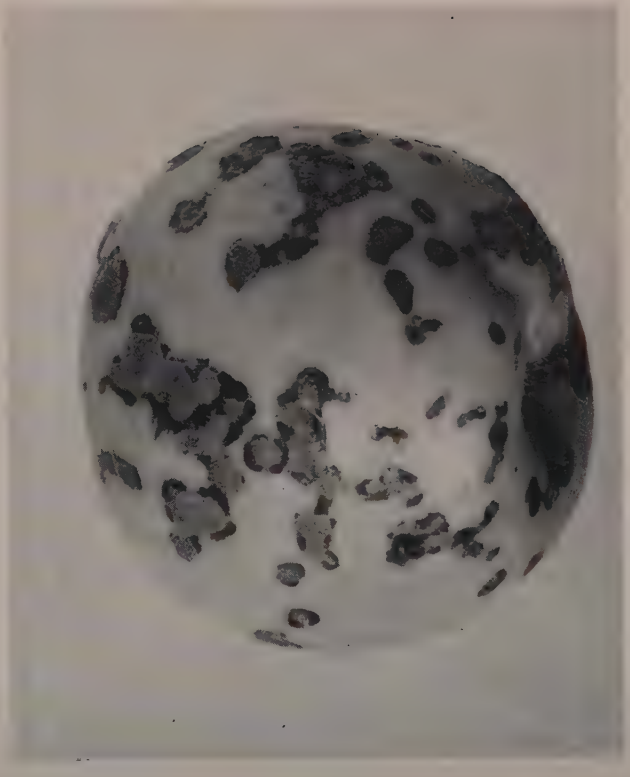

Fig. 2.—Granny Smith apple showing typical ring-spot symptoms with dark brown margins well developed on many spots.

Photo: L. H. Wright.

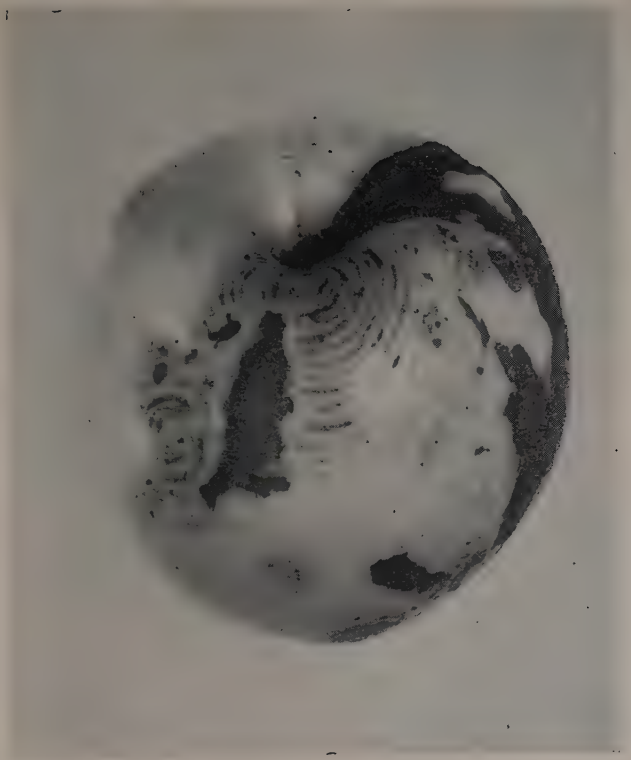

FIG. 3.—Granny Smith apple with both concentric ring and russet symptoms of ring-spot.

Photo: S. A. Rumsey

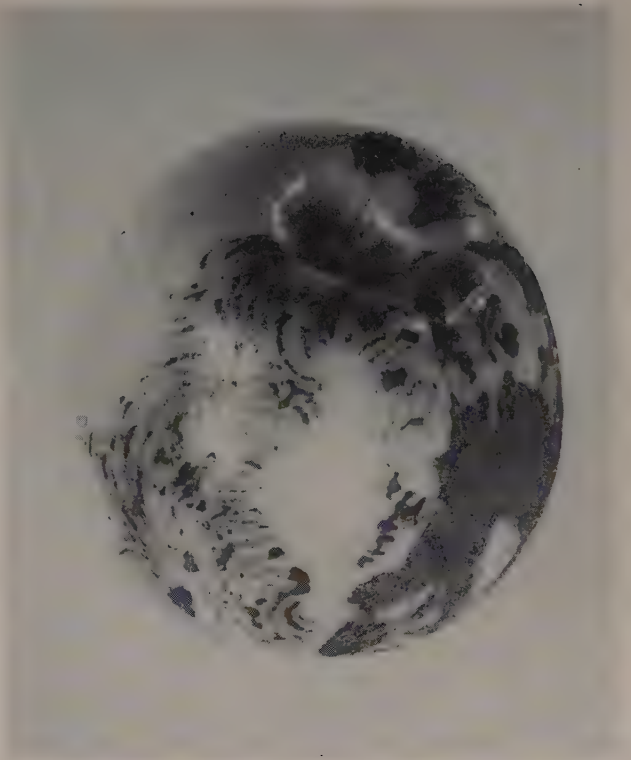

FIG. 4.—Fragmentary concentric rings and extensive russet areas on Granny Smith apple infected with ring-spot.

Photo: S. A. Rumsey

taken in 1949. Scion wood was taken from two Granny Smith trees known to have produced consistently severe symptoms for the three preceding years. Four diseased scions were grafted into each of eight normal Granny Smith trees and all scions grew.

No fruit was carried on scions during 1950, and no ring-spot symptoms were found in crops from the eight grafted trees. Results for 1951, 1952, and 1953 are summarised in Table I.

TABLE I. APPLE RING-SPOT ON GRANNY SMITH APPLES. NUMBERS OF FRUIT WITH AND WITHOUT SYMPTOMS PRODUCED BY 32 INFECTED SCIONS, 8 TREES INTO WHICH SCIONS WERE WORKED, AND 6 CHECK TREES

Year	Crop from 8 grafted trees				No. apples on 6 check Granny Smith trees	
	No. apples from infected scions		No. apples remainder of crop			
	Affected	Normal	Affected	Normal	Affected	Normal
1951	8	8	1	1,033	—	809
1952	30	33	4	1,823	—	1,373
1953	94	41	2	2,802	—	1,831

Each of the 32 scions produced fruit with ring-spot symptoms in at least one of the years under review. There is thus clear evidence that ring-spot is perpetuated in scions taken from infected trees.

Evidence of spread to other parts of the grafted trees is meagre. Although 62 per cent of apples produced by infected scions during a 3-year period showed ring-spot, only 0.1 per cent of the remaining crop from eight grafted trees showed typical symptoms during this period. Adjacent Granny Smith trees of the same age used as checks showed no ring-spot symptoms. With only 7 apples out of 5,665 showing transmission, evidence for the presence of a virus is scarcely conclusive, yet the virus hypothesis appears to fit the known facts better than any other.

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RESPONSES OF COBALT-DEFICIENT LAMBS TO COBALT AND TO VITAMIN B_{12}

By E. D. Andrews, Animal Research Station, Department of Agriculture, Wallaceville, and J. P. Anderson, Department of Agriculture, Invercargill

(Received for publication, 22 December 1953)

Summary

1. Unthrifty lambs grazing a cobalt-deficient pasture responded at least equally as well to vitamin B_{12} injected at the rate of 100 μg. a lamb a week as to cobalt dosed orally at the rate of 7 mg. a lamb a week. Superior average weight gains in favour of vitamin-B_{12}-injected lambs were non-significant.

2. Lambs responded significantly to 1,000 μg. vitamin B_{12} administered orally each week, but at the dose rate given, growth was sub-optimal.

3. Lambs responded briefly to single massive injections of 1,000 μg. vitamin B_{12}, but after 2 weeks continued to deteriorate in condition.

4. Observations are discussed in relation to the diagnosis and control of cobalt deficiency disease.

Introduction

It is now well estblished that in ruminants, vitamin B_{12} is synthesised by rumen organisms from cobalt contained in feed (Abelson and Darby, 1949; Hale *et al.*, 1950), and that cobalt-deficient sheep will respond at least equally as well to injections of vitamin B_{12} as to orally-administered cobalt (Smith *et al.*, 1951; Marston and Lee, 1952; Hoekstra *et al.*, 1952; Anderson and Andrews, 1952).

In a previous trial (Anderson and Andrews, 1952) with unthrifty lambs grazing a cobalt-deficient pasture, control animals gained on an average only 2.2 lb. over a 9-week experimental period, lambs dosed orally with cobalt sulphate at the rate of 4 mg. Co. a lamb a week gained 18.8 lb., and those injected intramuscularly with vitamin B_{12} at the rate of 100 μg. a lamb a week gained 23.0 lb. Only four lambs received the vitamin B_{12} treatment and the weight gain difference in favour of this group as compared with the cobalt-dosed group was non-significant.

In the present trial carried out at the Winton Experimental Farm, Southland, possible differences in response to intramuscularly-injected vitamin B_{12} and oral cobalt sulphate were again examined using a greater number of lambs in the vitamin-B_{12}-injected group. In view of the fact that the numbers and types of rumen organisms are grossly altered in cobalt deficiency (Gall *et al.*, 1949), it seemed not unlikely that after cobalt dosing appreciable time could be required for the production of effective amounts of vitamin B_{12} in the rumen so that during the earlier stages a more rapid response to injected vitamin B_{12} than to oral cobalt might be expected. Although the New Zealand official recommendation (1949) is that cobalt doses for deficient sheep should contain the equivalent of 2 mg. cobalt and be given twice each week, it is common experience that weekly doses of equivalent or greater amount will restore apparently normal health, and Lee (1950) states that cobalt deficiency may be completely controlled by drenching once each week

with 7 mg. cobalt. In the present experiment the more convenient practice of drenching once a week was adopted and the amount of cobalt given increased to 7 mg. for each lamb.

At the time when the present work was contemplated there appeared to be no available data concerning the response of cobalt-deficient sheep to orally-administered vitamin B_{12} and it was therefore thought of interest to include an orally-dosed group of lambs in the experiment. As it seemed possible that some vitamin B_{12} might be destroyed or otherwise rendered unavailable before reaching the absorptive areas, and because work with rats (Chow *et al.*, 1951) has shown that only a relatively small, though unspecified fraction of the vitamin is absorbed from the alimentary tract, the oral dose was arbitrarily fixed at ten times the rate of injected vitamin B_{12}.

It has been shown (Walker and Hunter, 1952) that in human pernicious anaemia single massive injections of 1,000 μg vitamin B_{12} will ensure remission of the disease for prolonged periods of time. In view of this it was considered possible that sufficiently large single injections of the vitamin might be more conveniently employed in field diagnosis of cobalt deficiency than cobalt dosing, since cobalt must be given at short intervals to be fully effective (Filmer, 1941). A group in which each lamb received a single injection of 1,000 μg. vitamin B_{12} was therefore included in the present trial.

Experimental Procedure

For the purposes of the experiment, 50 Romney-Southdown cross-bred lambs were chosen. These were run togther as one mob on a paddock known from previous experience to be cobalt-deficient. Prior to the commencement of the trial lambs had been given each a single dose of 10 to 15 g. phenothiazine on 2 February 1953, but no regular anthelmintic treatment had been carried out because in a previous year trials had failed to show that parasites were a contributory cause of lamb unthriftiness on this farm. By February virtually all animals were showing signs of unthriftiness as judged by small and erratic gains, or in most cases actual losses in weight. On 26 February when the lambs were approximately 5 months old they were divided as evenly as possible on the basis of body-weights into five groups of 10 lambs each and given the first of the following treatments:

Group A: Cobalt orally, 7 mg. a lamb a week.
B: Vitamin B_{12} injected, 100 μg. a lamb a week.
C: Vitamin B_{12} orally, 1,000 μg.* a lamb a week.
D: Vitamin B_{12} injected, 1,000 μg. a lamb once only.
E: Control.

Except for one weighing missed between the 12th and 14th week, lambs were weighed at weekly intervals.

Between the 3rd and 4th week all groups showed marked weight losses, and the existence of a profuse scour common to nearly all lambs

*Owing to an error, for the 1st, 2nd, and 3rd weeks lambs received only 667μg. each. Thereafter, doses were at the planned rate of 1,000 μg. vitamin B_{12} a lamb a week.

suggested possible parasitic infestation. Accordingly, from the 4th week all animals were dosed at approximately fortnightly intervals with phenothiazine at the rate of 20 g. a lamb until the end of the experiment. Although a few lambs continued to show some scour, in the majority, scouring ceased within a week of their receiving the first dose. All groups gained weight. In the case of the control lambs, gains were slight and persisted for only two weeks. On the other hand, lambs in Groups A and B increased rapidly in weight for two weeks and thereafter maintained fairly steady gains until the end of the experiment.

In the earlier stages of the trial one lamb from each of Groups A, B, and D failed to respond to treatment and died. On the other hand, five lambs from the control group (E) were either killed in extremis or died during the course of the experiment, presumably as a result of cobalt deficiency.

Part of the trial involving lambs in Groups C and D was terminated after 9 weeks. Thereafter, the animals in these two groups were dosed cobalt at the same rate as those in Group A.

After 15 weeks the whole experiment was terminated. The animals were slaughterd and blood samples and livers were taken from lambs in Groups A, B, and E in order to gain information concerning the biochemical effects of cobalt deficiency and to examine further the apparent identity of cobalt deficiency with vitamin B_{12} deficiency. Analytical results will be reported elsewhere.

RESULTS AND DISCUSSION

The effects of treatments on growth are set out in Fig. 1, which shows group average weight gains of lambs surviving at the end of the experiment.

Comparative Effects of Cobalt Dosing and Weekly Injections of Vitamin B_{12}

Over the 15-week experimental period the average daily gains made by Groups A, B, and E (control) were 0.19 lb., 0.24 lb., and — 0.07 lb. respectively. The marked response to both cobalt and vitamin B_{12} is clearly evident.

There is no indication that during the first few weeks the response to injected vitamin B_{12} was appreciably better than that due to orally administered cobalt. Between the 5th and 15th week, Group B lambs tended to make increasingly better gains than those made by Group A, but at the end of the period the difference in favour of the former again proved non-significant ($0.2 > P > 0.1$).

The Effect of Oral Vitamin B_{12}

For the first 4 weeks oral dosing of vitamin B_{12} had no discernible effect. This may have been due to the reduced amounts of vitamin given in the first three drenches (see footnote). Between the 4th and 9th week, however, a comparison of gains made by Group C lambs with those of the control group showed that a highly significant response

($P < 0.01$) was obtained. But during this period the average daily gain made by Group C lambs was only 0.17 lb. as compared with 0.37 lb. and 0.41 lb. for Groups A and B respectively. Also the average daily gain of Group C lambs later rose to 0.27 lb. over the period between the 9th and 15th week, during which time the animals were receiving cobalt. These results indicate that under the conditions of the experiment the response to oral vitamin B_{12} was appreciably less than responses to oral cobalt and injected vitamin B_{12}.

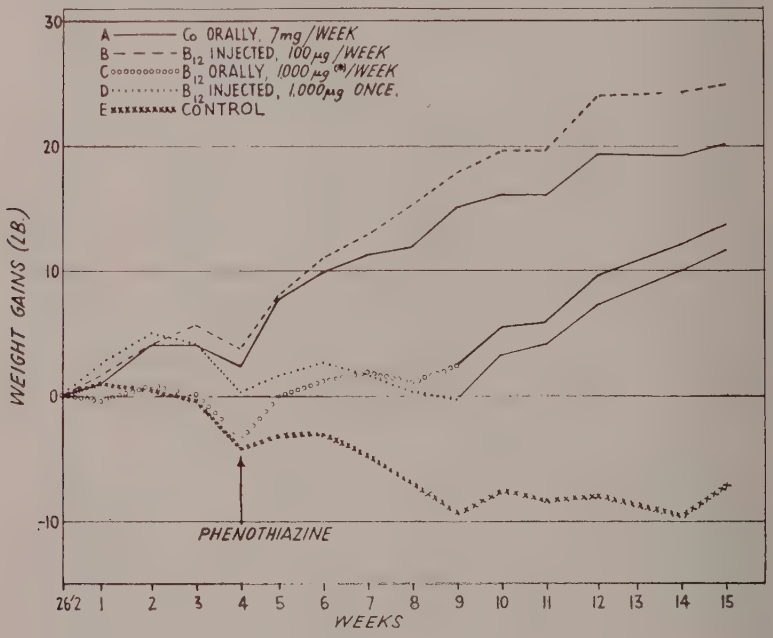

FIG. 1.—Weight gains of lambs under various treatments.

Weekly doses of 1,000 μg. vitamin B_{12} would provide each lamb with cobalt at the rate of 0.006 mg. a day, an amount which other work (Filmer and Underwood, 1937) would suggest was insufficient to exert a measurable effect against cobalt deficiency. It is probable, therefore, that the response shown was due to vitamin B_{12} *per se*, but the amount given was insufficient to promote optimal growth. Unfortunately our limited supplies of vitamin B_{12} did not permit the latter point to be examined further.

Effect of Single Massive Injections of Vitamin B_{12}

At first lambs in Group D responded abruptly to single injections of 1,000 μg. vitamin B_{12}. Although results may to some extent have been obscured by parasitism, it is, however, clear that the full effect of the injections lasted for about two weeks only. While some slight residual effect may have persisted, the growth curve between the 2nd and 9th week is similar to that for the control group. Group D lambs responded immediately and continuously when given cobalt.

The relatively brief response of cobalt deficient lambs to single injections of 1,000 μg. vitamin B_{12} is in contrast to the effect of similar amounts used in the treatment of human pernicious anaemia where remission of the disease was secured for periods ranging from 4 to 12 months (Walker and Hunter, 1952). Present results are consistent with the concept advanced by several writers (Smith *et al.*, 1951; Marston, 1952; Porter, 1953) that the sheep has a much higher requirement for vitamin B_{12} as compared with humans and possibly other non-ruminant species.

While it is not improbable that even more massive single injections of the order of several milligrams could arrest the course of cobalt deficiency for more prolonged periods, the use of large amounts of the vitamin for field diagnostic purposes is at present precluded on the grounds of cost (about 12s. 6d. a milligram).

GENERAL CONSIDERATIONS

The identification of cobalt deficiency with a deficiency of vitamin B_{12} now seems clearly established. It becomes necessary, therefore, to consider what part vitamin B_{12} is likely to play in the diagnosis and control of cobalt deficiency disease.

Where stock unthriftiness is not particularly marked, diagnosis is sometimes difficult. Clinically, cobalt deficiency is not readily distinguishable from other diseases which give rise to unthriftiness. Effective diagnosis in the field can often depend only upon carefully controlled cobalt dosing trials in which weight gains made by dosed and non-dosed groups of animals are compared. On present evidence vitamin B_{12} offers no advantages over cobalt as a practical means of field diagnosis. In the laboratory, diagnosis by examination of pasture or liver samples for cobalt content is time-consuming and expensive and results are not always easily interpreted in cases where the disease is not severe. Recent investigations into the function of vitamin B_{12} in metabolism do, however, suggest that more rapid and sensitive laboratory methods can be developed for the diagnosis of cobalt deficiency disease. Of these, estimation of the vitamin itself in the rumen, blood, or tissues of animals suspected of deficiency offers obvious possibilities.

Marston (1952) and Porter (1953) have reviewed the role of cobalt in nutrition with particular reference to the requirement of ruminants for vitamin B_{12}. It seems that cobalt is necessary for the elaboration by rumen micro-organisms of a number of vitamin-B_{12}-active compounds, including vitamin B_{12} itself, which is needed by the host. Given an adequate cobalt intake, cattle and sheep can manufacture their full requirement of vitamin B_{12}. It should, therefore, hardly be necessary to point out that in our present state of knowledge treatment with vitamin B_{12} seems unlikely to become of significant practical importance in the control of cobalt deficiency disease. In New Zealand, topdressing with cobaltised fertilizers remains the most economic means of ensuring continuous and adequate supplies of cobalt and, by extension, vitamin B_{12}. Where treatment of individual animals suffering from uncomplicated cobalt deficiency must of necessity be resorted to, adequate doses of cobalt frequently supplied will give satisfactory results (Filmer, 1941).

Acknowledgments

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MEASUREMENT OF FEED INTAKE BY GRAZING CATTLE AND SHEEP

IV. A SOURCE OF ERROR IN THE CHROMOGEN TECHNIQUE OF ESTIMATING THE DIGESTIBILITY OF FODDERS

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(Received for publication, 7 December 1953)

Summary

(1) It is recommended that chromogen concentrations be expressed as optical densities without recourse to a chromate standard.

(2) The stability of chromogen solutions, prepared by extracting fresh faeces with 85 per cent acetone in the dark, was examined by measurement of optical density at 406 mμ.

(3) The optical density of extracts kept in the dark remained constant for six hours, then increased by 20 to 30 per cent over the next 10 days.

(4) The optical density of extracts exposed to light increased rapidly, the rate of increase depending on the intensity and time of exposure. With sufficient light, the changes in optical density indicated destruction of pigments.

These results suggest that to obtain reproducible estimates of the mixed chromogens in acetone extracts of faeces, light should be excluded both during and after extraction, and the observation of optical density should be made within six hours of the preparation of the extract.

Introduction

Although the chromogen technique of estimating the digestibility of forages was announced three years ago by Reid and his co-workers[1], there have been published few investigations comparing it with orthodox digestibility trials, and none designed to test the method of estimating the mixed chromogens in acetone extracts of fodders and faeces. Since Reid's data showed the method to be the most accurate yet proposed for indirect estimation of digestibility of grass consumed by grazing animals, a series of digestibility trials using cows fed grass was commenced to compare it with the faeces nitrogen method[2] developed at this Station. Inexplicable discrepancies in chromogen determinations in faeces extracts caused a postponement of the experiments, and a study of the method of estimation which is reported in this paper.

Expression of Chromogen Concentration as Optical Density

Reid *et al.* encountered difficulties in the evaluation of extracts of high and low chromogen concentrations, and suggested that these difficulties arise "because extracts of chromogen do not correspond to the Beer-Lambert law in precisely the same manner as solutions of Na_2CrO_4"[3].

Solutions of Na_2CrO_4 do not in fact obey Beer's law, because at low concentrations hydrolysis occurs and equilibrium is established between $CrO_4^=$ and $Cr_2O_7^=$ ions each of which has a characteristic

absorption spectrum[4]. The equilibrium is determined by the dilution of the salt. Hence deviations from linearity are encountered at low dilutions. When chromate solutions are used for calibrating photoelectric instruments, it is usual to add small amounts of alkali to solutions to stabilize the equilibrium on the $CrO_4^=$ side[5].

Solutions of chromogens in acetone, on the other hand, obey Beer's law precisely. Acetone extracts of various pasture and faeces samples have been tested, and in every case the law was found to hold over the range of optical densities 0 to 1, when light of wavelength 406mμ was used.

The formula developed by Reid *et al.* to express chromogen concentrations in terms of Na_2CrO_4 was

$$y = 57.39 - 28.74x$$

where y = concentration of chromogen per 100 ml. extract
x = log per cent transmitted light.

This may be written

$$y = 28.74\ (1.998 - x)$$

or approximately

$$y = 28.74\ (2 - \log T)$$ where T = per cent transmitted light.

It is apparent that the calibration formula comprises the multiplication of the optical density $(2 - \log T)$ of the test chromogen solution by a constant which presumably involves the optical density of the standard chromate solution. Since the optical density of a solution is a precise physical measurement, it is preferable to express relative concentrations of extracts of unknown chromogens in terms of optical density and avoid the use of a reference substance. This method has already been adopted by Kane *et al.*[6]

Experimental Procedure

Extraction of chromogens

This followed essentially the procedure of Reid *et al*[1]. Fresh faeces samples were protected from light. Use of a blendor driven by a motor above the blending jar eliminated heating of solutions, and also eliminated troubles due to leakage at the gland of the conventional Waring blendor. Extractions and filtrations were carried out in weak diffused daylight in a room facing South and all extracts were left in the dark. Filtration of an aliquot, before final dilution, was carried out through sintered glass, as the pigments were more readily washed through this than through filter paper. Optical density was read on a Beckman Model DU spectrophotometer. Readings were usually taken within 24 hr. after the preparation of an extract.

Stability of chromogen solutions

1. Pasture chromogen solutions: Solutions, kept in the dark at room temperature, did not change in optical density over long periods (1 year) thus confirming the observations of Reid *et al.*[1]

2. Faeces chromogen solutions: Extracts of a number of specimens of fresh faeces were prepared, and kept in the dark. The type of result obtained by reading the optical densities at frequent intervals after extraction is presented in Fig. 1, which shows curves obtained

from three different samples. These curves indicated the presence of a major source of error (up to +20 per cent) in the technique of estimating chromogens in faeces extracts as used in this laboratory. Furthermore, repeat examinations of the same samples resulted in similar trends but marked displacement. It was evident that there were unknown variables in the procedure. Since light appeared to be the most variable factor likely to affect the pigments this aspect was studied in greater detail.

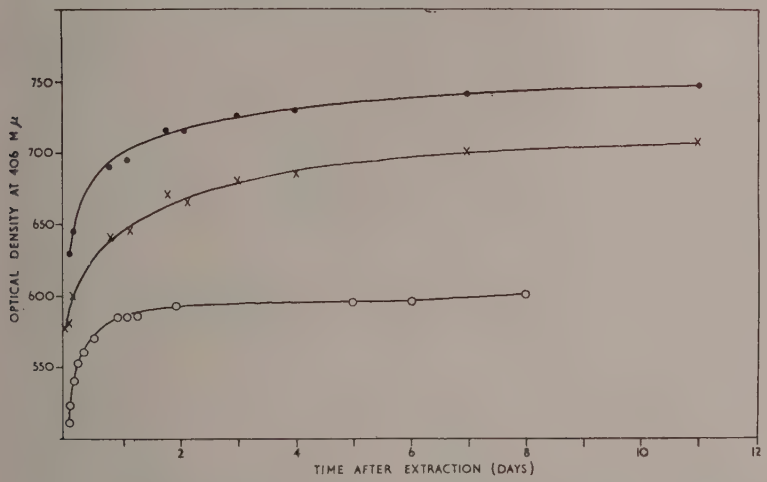

FIG. 1.—Changes in optical density of acetone extracts of three different samples of faeces

Effect of light on acetone extracts

Acetone extracts of faeces were prepared by two procedures designed to exclude light:

(a) Extraction in vessels covered with black paper, and filtration in minimum light within a cupboard painted black inside.

(b) Extractions and filtrations in a dark room using a shielded red safe-light when necessary. Whatever the mode of extraction, the final filtration through sintered glass was done in the dark room, and extracts were kept and handled in the dark room at room temperature. The methods gave comparable results (Table I) so that subsequent investigations were carried out with the more convenient method (a).

To observe the effect of light on the optical density, portions of the extracts, transferred to glass-stoppered flasks, were exposed to light of different intensities for different times, then returned to the dark. Different light intensities were obtained by placing the flasks in predetermined positions in a room receiving light from a South window. An approximate measurement of light intensity was made with a

TABLE I. CHANGES IN OPTICAL DENSITY OF ACETONE EXTRACTS OF FAECES PREPARED AND KEPT IN DARK

Initial Density	Per cent of initial optical density at indicated time after extraction						
	1–2 hr.	2–4 hr.	4–6 hr.	6–8 hr.	10–14 hr.	18–26 hr.	200–300 hr.
	A. *Prepared in dark room*						
.339		100		100	102	103	
.285		100	100		102	105	
.209				102		108	
	B. *Prepared in dark vessels*						
.480	100		100			106	120
.380			101			107	122
.395	101	100				105	131
.210				101		106	128
.214	100	100	101	101		106	
.257	100	100	100	100		104	
.256	100	100	100	100		104	
.285	100		101		103	105	126
.295		100		101		106	132
.284		100		101		104	129
.237	101	101	101	102			
.281	100	100	100	101			
.186		102	103		105		
.245		100	102		104		
.224		101	101		104		
.192		100	100		103		

Weston photoelectric exposure meter. The optical densities of extracts were read immediately after exposure and at intervals thereafter. Results from a single faeces sample are presented in Fig. 2. This series of curves is typical of all faeces extracts similarly treated.

It will be noted that the effects of both electric light (50 w. filament lamp) and weak daylight were very similar. Furthermore, the time of exposure under a given intensity evidently modified the results quite considerably. When the results from this and similar experiments were examined, it was found that they could be grouped according to the product of light intensity and time (foot-candle-minutes). It was decided therefore to study this effect in more detail.

Effect of quantity of light on optical density

Two additional experiments were conducted to observe the effect of the quantity of light (intensity × time of exposure) on optical density. Since the experiments conducted on different days with different samples of fresh faeces yielded similar results, only one will be considered in detail. The procedure adopted was similar to that already described. The times and intensities were so selected that some replication in the time × intensity observations was obtained with different times and intensities. All optical densities were calculated as percentages of the optical density at the first observation made on the extract prepared in the dark.

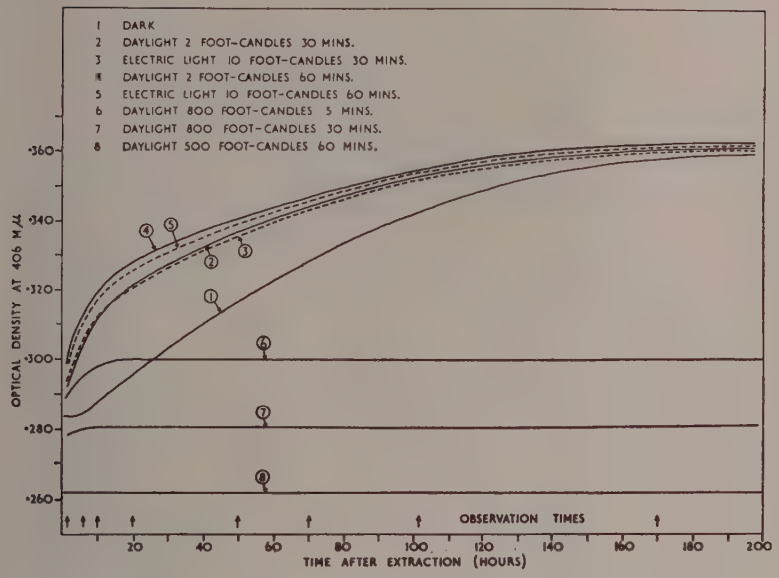

FIG. 2.—Effect of light on optical density of an acetone extract of faeces

Results presented in Table II may be summarised as follows:

(1) With no exposure of the extract to light little change in optical density took place in the first 5 hours, after which it increased steadily for some 46 hours. The rate of increase then became slower and was negligible by 12 days.

(2) With exposures to even small quantities of light (20 f.c.m.), immediate increase in optical density occurred. Larger amounts of light accelerated the increase in optical density. The final results obtained with all quantities up to 500 f.c.m. were similar.

(3) With quantities of about 1,000 f.c.m. or greater, the optical density became constant after 22 to 30 hr., the final figure being lower, the greater the amount of light.

(4) Very similar results were yielded by the same quantities of light obtained with different times and intensities (c.f. Flasks 6 and 7, and 8, 9 and 10). At 2,000 and 4,000 f.c.m., however, exposures under light of 400 foot-candles yielded lower optical densities than were obtained with 200 foot-candles. This may be due to the fact that on the day of the experiment an intensity of 400 foot-candles could be obtained only at a North-facing window and, though the flasks were shaded from direct sunlight, conditions may not have been comparable with those in the room facing South.

TABLE II. EFFECT OF LIGHT ON OPTICAL DENSITY OF AN ACETONE EXTRACT OF FAECES

Flask No.	Exposures			Per cent of initial optical density (.295) at indicated time after extraction								
	F.C.M.	F.C.	Time (Min.)	0–1 hr.	2.5 hr.	5 hr.	11 hr.*	22 hr.	30 hr.	46 hr.	143 hr.	287 hr.
1	0	0	0	100	100	101	103	106	108	112	127	132
2	10	2	5	100	102	102	104	108	109	114	127	132
3	20	2	10	101	103	103	105	109	110	115	127	133
4	40	2	20	103	104	105	—	112	113	117	129	132
5	250	50	5	101	105	105	107	112	113	118	128	131
6	500	50	10	103	107	109	—	115	116	119	127	130
7	500	100	5	102	106	108	110	114	116	120	127	130
8	1000	50	20	104	110	112	—	119	119	121	124	125
9	1000	100	10	103	109	112	—	118	118	121	124	125
10	1000	200	5	103	108	111	114	117	119	120	124	126
11	2000	100	20	104	110	111	—	117	116	117	119	118
12	2000	200	10	104	111	112	—	117	117	118	120	120
13	2000	400	5	102	105	106	—	108	108	109	109	109
14	4000	200	20	105	107	109	—	112	112	112	112	111
15	4000	400	10	102	105	104	—	106	106	106	106	105
16	8000	400	20	101	103	103	103	103	105	105	104	103
17	16000	400	40	98	100	99	—	100	100	101	100	99

*Owing to a failure of the instrument after the recorded readings had been taken, no further observations were taken at this time.

DISCUSSION

The results obtained throughout this investigation consistently indicated that even small amounts of light initiate changes in the pigments in 85 per cent acetone extracts of faeces leading to increases in optical density. Similar changes take place in the absence of light but are delayed for some hours. Superimposed upon this effect, which increases with increasing quantities of light, there appears to be destructive action, also a function of the amount of light.

These conclusions are of considerable importance in studies of faeces pigments generally, and in the determination of the mixed pigments in the "chromogen" method in particular. In the observations of Irvin and his co-workers on the individual pigments in cows' faeces[7], no account appears to have been taken of the possible effects of light on the pigments, though these authors have commented on the possibility of photo-oxidations and auto-oxidations which may be the basis of the changes reported herein.

It is obvious that results obtained in the estimation of mixed chromogens in faeces extracts are to a great extent dependent upon the conditions of light during the preparation of extracts, and by the time lapse between extraction and the reading of the optical density. In the routine estimation of chromogens in faeces, extracts were prepared in about 100 foot-candles (daylight), the exposure time being 10–15 min. The final filtration was done in less than 10 foot-candles (daylight) and occupied a further 10 min. Since the time of reading optical densities was not fixed, quite variable results could have been obtained, even though duplicate determinations run together gave excellent concordance.

In digestibility trials, which initiated this investigation and which had to be abandoned because of the anomalous results obtained, the apparent output of chromogen greatly exceeded the intake, recoveries ranging from 98 to 120 per cent. This was at first ascribed to inefficient extraction of the grass pigments, but it now appears that overestimation of the chromogens in faeces could have caused the results obtained. This effect may have been responsible for the 129 per cent recovery of chromogens reported by Kane *et al.*[8], though there still remains the anomaly mentioned by these authors that application of Reid's formula to faeces chromogens still gave excellent results in the estimation of digestibility.

The validity of this explanation of over-recovery of chromogens rests on the assumption that the isosbestic point found by Reid *et al.*[1] was established with a procedure yielding minimum or low faeces chromogen figures. The instructions given by these authors for the determination of chromogens in faeces do not indicate that this is necessarily so. These instructions are specific with regard to the protecting of faeces samples and their extracts from light, but the light conditions during the preparation of extracts are not stated, nor is the time permissible between extraction and reading of optical density specified.

On the basis of the observations reported in this paper, it is suggested that all possible precautions be taken to exclude light from extracts, both during and after preparation, and that readings of optical density be made within six hours of the preparation of the extract. That this procedure should yield results reproducible within one per cent is apparent from the data in Table I.

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APPLE ROOTSTOCK TRIALS

I. STURMER ON EAST MALLING STOCKS, NORTHERN SPY, AND OWN ROOTS

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Summary

The growth and cropping of Sturmer on Northern Spy, "own roots" and five East Malling rootstocks during twelve years following planting are described.

M. XII was the most vigorous stock. The next largest trees were those on M. XV and "own roots," which were of similar size. The least vigorous stocks were Northern Spy, included as a check, and the rootstocks M. I, M. XIII and M. XVI which did not differ significantly from Northern Spy.

Total production of fruit for the twelve-year period was highest on M. XII and "own roots", both of which gave similar yields. Next, but considerably lower in production, were Northern Spy and M. I, M. XV and M. XVI, none of which differed significantly from Northern Spy. M. XIII gave a lower yield than Northern Spy.

Considered in relation to size of tree, cropping was delayed by M. XII and M. XV. "Own-rooted" trees, although similar to M. XV in vigour, were remarkable for precocious bearing.

From the aspect of early cropping combined with heavy total production and adequate vigour, "own-rooted" trees show considerable promise at this stage of the trials. However, trees on M. XII with a similar total production are now yielding heavier crops.

Introduction

The two apple rootstock trials described in this paper were first planted in 1934 and 1935 at the former Plant Research Station, Palmerston North. Following re-organisation of the Department the trees were transferred to the research station of the newly-formed Plant Diseases Division at Auckland, where they were replanted in 1937. As transplanting severely checked growth of the three and four-year old trees, previous growth records were discarded and the trials were regarded as commencing from the date of replanting. An account of the growth and cropping of trees on various rootstocks is given in this article, which is a progress report.

Experimental Material and Method

Trial I included trees of the Sturmer variety on the East Malling rootstocks Nos. I, XV and XVI, with the common New Zealand stock Northern Spy as a check. The trees were 4 years old from the bud when replanted.

Trial II consisted of Sturmer on "own roots", Northern Spy and East Malling Nos. XII and XIII. With the exception of the "own-

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rooted" Sturmers, which were two-year rooted layers, the trees were three years old from the bud at replanting.

Although trees in the two trials were of the same variety, Sturmer, and were planted at the same time, separate trials were established because of the difference in age of trees. However, for ease of comparison of trees on different rootstocks irrespective of age, both trials were accommodated in the same randomized blocks, replicates of Trial I being planted in one half of each block and replicates of Trial II occupying the remaining half. There were five replications of each rootstock.

Planting was done on the square at 20-ft. spacing. The soil was a podsolized clay derived from argillaceous sandstone.

The trees were pruned to form six permanent leaders and general pruning treatment followed the "long-lateral" system. Except for the thinning of crowded shoots, lateral growth was left unpruned in the early years to induce early cropping, especially of trees on the more vigorous rootstocks.

Growth was recorded annually by measurements of trunk girth at 9 in. above bud union and mean height and spread of tree, the latter being measured in two fixed directions at right angles.

Yield of fruit was recorded by weighing and included windfalls which were gathered and weighed twice weekly for approximately a month before picking.

RESULTS AND DISCUSSION

It has not been possible to make allowance for the effect of transplanting the trees from Palmerston North to Auckland. The check that this gave to three and four-year-old trees may have influenced vigour of growth and age at which the trees came into bearing, and all stocks may not have been affected to the same extent.

Rootstock Effect on Tree Growth

Table I presents data showing the size of trees in Trial I on the different rootstocks in 1949, twelve years after planting.

TABLE I.—AVERAGE GIRTH, SPREAD AND HEIGHT OF STURMER ON MALLING I, XV, XVI AND NORTHERN SPY ROOTSTOCKS (PLANTED 12 YEARS)

Rootstock	Trunk girth (cm.)	Spread (m.)	Height (m.)
Northern Spy	29.3	2.64	2.36
M. I	32.7	2.74	2.32
M. XV	39.9	3.47	3.06
M. XVI	30.4	2.24	2.16
Difference required for significance at 5%	6.3	0.78	0.41
at 1%	8.8	1.10	0.58

It will be seen that the trees fall into two groups. The first group includes trees on Northern Spy, M.I. and M. XVI, which do not differ significantly in trunk girth, spread and height. The second group is represented by trees on the vigorous stock M. XV. These are significantly larger in all respects than trees in the first group except in the case of M.I., where the difference in spread is not significant.

The growth of trees on rootstocks included in the second trial is shown in Table II.

TABLE II.—AVERAGE GIRTH, SPREAD AND HEIGHT OF STURMER ON "OWN ROOTS" AND ON MALLING XII, XIII AND NORTHERN SPY ROOTSTOCKS (PLANTED 12 YEARS)

Rootstock	Trunk girth (cm.)	Spread (m.)	Height (m.)
Northern Spy	32.6	2.75	2.68
M. XII	51.0	4.08	3.94
M. XIII	33.3	2.71	2.50
"Own Roots"	39.0	3.32	3.10
Difference required for significance			
at 5%	3.9	0.35	0.54
at 1%	5.5	0.49	0.76

Here the most noteworthy result is the outstanding vigour of trees on M. XII (Fig. 1) in comparison with all other rootstocks. "Own-rooted" trees (Fig. 2) are larger in all respects than trees on M. XIII, and surpass trees on Northern Spy (Fig. 3) in girth and spread, but not significantly in height. The difference between the least vigorous stocks, M. XIII and Northern Spy, is not significant.

Differences in age of trees preclude direct comparison of rootstocks in the two trials. Nevertheless, the inclusion of Northern Spy in both trials as a check makes indirect comparison possible. On this basis, M. XII is the most vigorous stock, followed by M. XV and "own roots" approximately equal, and finally by M. I, M. XIII, M. XVI and Northern Spy, forming a single group of similar and less vigorous rootstocks.

Rootstock Effect on Cropping

(a) *Total Crop*: The total crop for the twelve-year period of trees on different rootstocks in the two trials is shown in Table III.

In Trial I, differences in yield between the four rootstocks are not significant. In the second trial, trees on M. XII and "own roots", while not differing significantly from each other, produced a greatly increased total crop in comparison with Northern Spy and M. XIII. The difference in favour of Northern Spy when compared with M. XIII is significant at 5 per cent level.

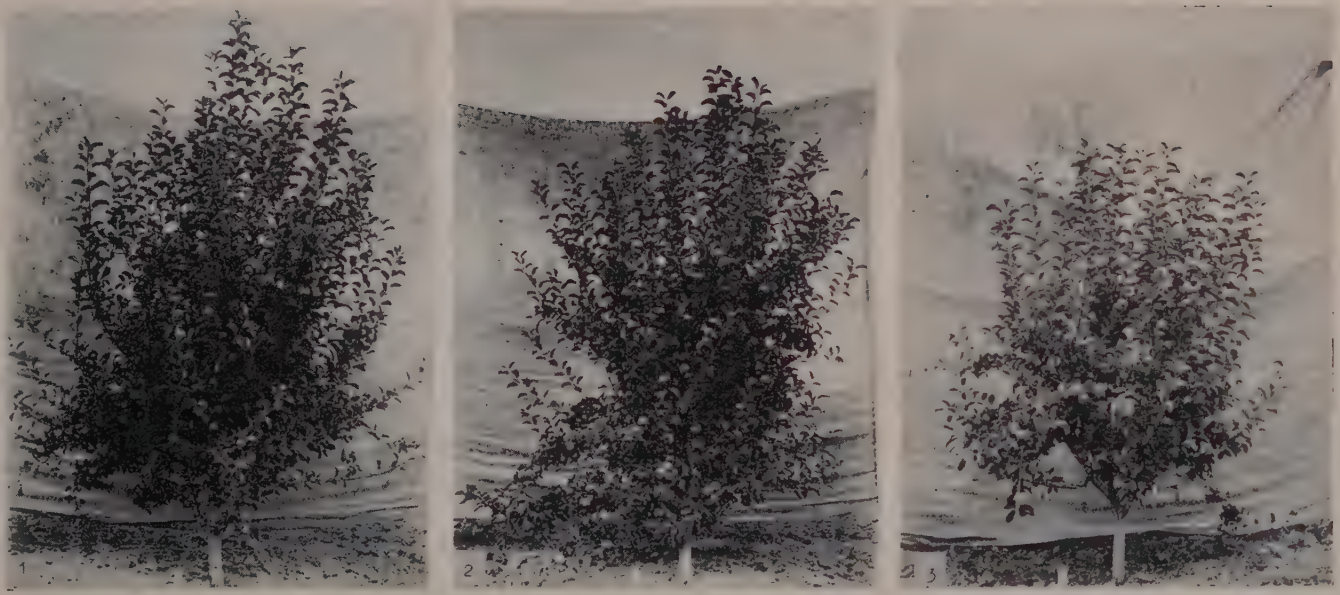

Fig. 1.—Sturmer on M. XII rootstock. Planted 7 years.
Fig. 2.—Sturmer on "own roots." Planted 7 years.
Fig. 3.—Sturmer on Northern Spy. Planted 7 years.

TABLE III.—TOTAL CROP (LB. PER TREE) OF STURMER ON DIFFERENT ROOTSTOCKS, 1937-1949 (TREES PLANTED 12 YEARS)

Trial I		Trial II	
Rootstock	Crop (lb. per tree)	Rootstock	Crop (lb. per tree)
Northern Spy	568.4	Northern Spy	722.2
M. I	665.6	M. XII	1053.0
M. XV	733.4	M. XIII	544.0
M. XVI	570.6	"Own Roots"	1029.2
Difference for significance— at 5%	291.9		177.3
at 1%	411.9		250.2

Again using as a basis of comparison the check rootstock Northern Spy common to both trials, the results indicate the following grouping of stocks in the two trials, for total yield of fruit:—

1. M. XII and "own roots";
2. M. I, M. XV, M. XVI and Northern Spy;
3. M. XIII.

(b) *Earliness of Cropping*: As the record of total crop gives no information on the age at which trees on different rootstocks came into bearing, accumulated crops from year to year are shown in Table IV.

TABLE IV.—ACCUMULATED TOTAL CROPS OF STURMER ON DIFFERENT ROOTSTOCKS, 1937-1949. (LB. PER TREE: LEADING ROOTSTOCK IN HEAVY TYPE)

	1937–42	1943	1944	1945	1946	1947	1948	1949
Trial I								
Northern Spy	**11**	24	58	112	209	276	439	568
M. I	10	**25**	**78**	**160**	**272**	**349**	525	665
M. XV	4	15	46	113	235	327	**551**	**733**
M. XVI	9	**25**	68	137	233	306	453	570
Trial II								
Northern Spy	**9**	**20**	64	130	262	365	587	722
M. XII	1	6	40	127	291	468	779	**1053**
M. XIII	4	16	44	87	159	251	434	544
"Own Roots"	4	18	**85**	**195**	**361**	**506**	**802**	1029

In Trial I it will be seen that early cropping was induced by M. I, M. XVI and Northern Spy, with the trees on M. I maintaining a lead over all stocks from the seventh year until they were passed in the eleventh year by M. XV. It will be noted that the larger trees on M. XV, although slower in cropping, had at eight years equalled the production of trees on the check rootstock, Northern Spy.

The figures for Trial II show that trees on Northern Spy, "own roots" and M. XIII came into production quickly, the "own-rooted" trees holding a lead over all stocks from the seventh to the eleventh year. Although they carried relatively light crops, the large size of trees on M. XII enabled them at nine years to pass in total production the check trees on Northern Spy.

(c) *Annual Crops*: The data so far presented have dealt with accumulated crops, representing total production, firstly for the whole period of the trial and secondly, from year to year. In Figs. 4 and 5 annual crops on rootstocks included in the two trials are shown, to indicate seasonal fluctuation in cropping and the size of crop in any given year.

Although rootstocks in Trial I did not differ significantly in total production, Fig. 4 shows that in the two final years the larger trees on M. XV bore appreciably heavier crops than trees on the less vigorous M. I, Northern Spy and M. XVI. The diagram also shows that in 1947, ten years after planting, trees on all stocks gave the first indication of slight biennial bearing.

The early and consistently heavy annual cropping of "own-rooted" trees throughout the trial period is illustrated in Fig. 5. Up to 1946 the annual crops from these trees exceeded those on all other stocks and were surpassed in the following years only by M. XII. Crops for the final year, 1949, show an increasing difference between M. XII and

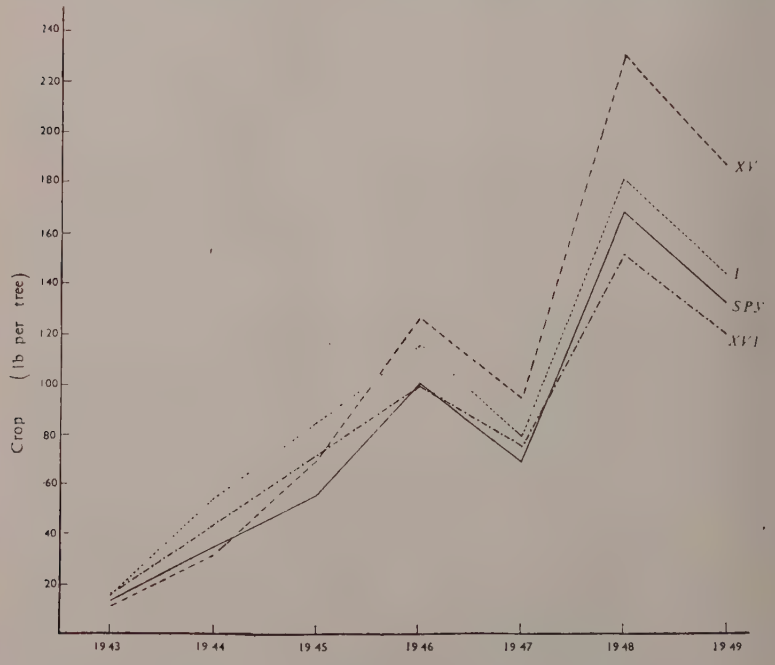

FIG. 4.—Annual Crops of Sturmer on Northern Spy and East Malling Rootstocks I, XV and XVI.

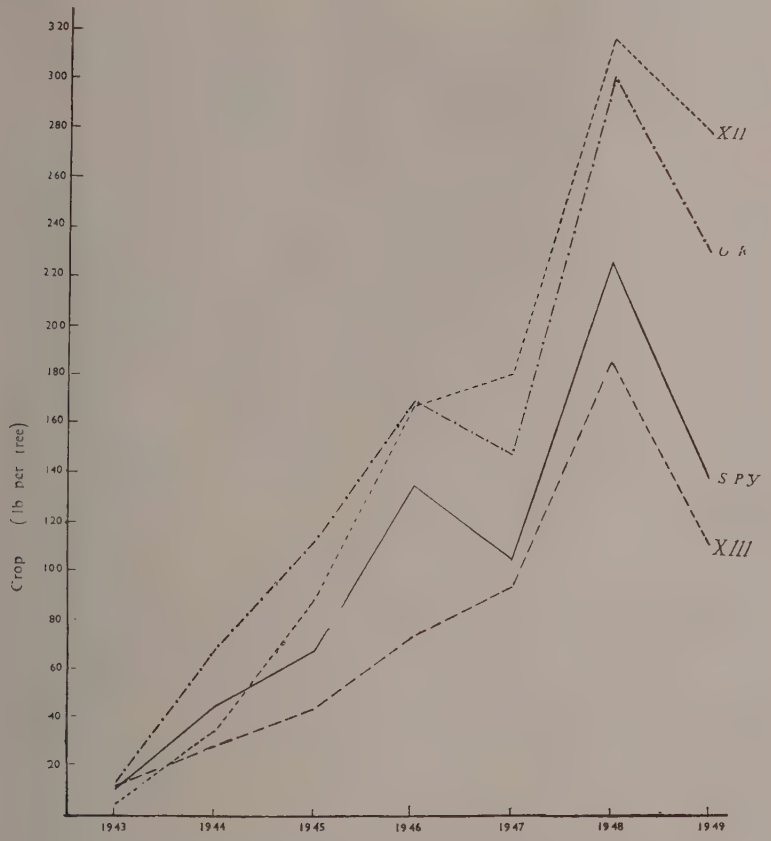

FIG. 5.—Annual Crops of Sturmer on Northern Spy, "Own Roots" and East Malling Rootstocks XII and XIII.

"own roots" in favour of the former. Excepting the year 1943, cropping on M. XIII was consistently inferior to that on Northern Spy.

Fig. 5 also shows that, as in Trial I, the first evidence of slight biennial bearing appeared in the tenth year from planting, but on this occasion in trees on only two of the stocks, Northern Spy and "own roots." Trees on M. XII and M. XIII were two years later in developing this tendency.

CONCLUSIONS

With Sturmer as scion variety, M. XII has produced the largest trees and also, with "own roots", the heaviest yields. If yield is considered in relation to size of tree, fruit bearing was delayed by M. XII. The trees on this stock did not begin to crop heavily until the eleventh year and still showed great vigour at the end of the period covered by this progress report.

Trees on "own roots" have given outstanding results, combining satisfactory vigour of growth with early cropping and a total production equalled only by the much larger trees on M. XII. However, crops for the final year indicate that M. XII is now outstripping "own roots."

M. XV shows no promise as a rootstock for Sturmer, as although trees are similar in size to those on "own roots", yields have been much lower.

The performance of Sturmer on Northern Spy is in keeping with experience in most New Zealand orchards that, with this variety, the stock does not produce trees of satisfactory size and cropping capacity. Similarly, M. I, M. XIII and M. XVI have in these trials proved inferior as rootstocks for this variety. The behaviour of trees on M. XVI, a vigorous stock in England (Hatton, 1935), supports the earlier statement of Woodhead (1946) that this rootstock did not thrive on clay soil.

Until the trials have progressed for a further period it will not be possible to reach a final conclusion on the relative merit of M. XII and "own roots", the two stocks which have so far given the best results.

ACKNOWLEDGMENTS

The authors wish to express their thanks to Mr. C. G. Aldridge, Fruit Research Station, and Mr. C. E. K. Fuller, now of the Department of Agriculture, for their assistance in recording over a considerable period of the trials; also to Mr. W. B. Taylor, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, for statistical analysis of the data.

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SOIL CONSERVATION SURVEYS IN NEW ZEALAND

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Summary

A technique for making Soil Conservation Surveys is described. This has three phases:

(1) Land Inventory mapping, which is the collecting and recording of the physical factors affecting land-use;

(2) Land Capability mapping, in which the capability of the land is assessed and the range of uses for each of the Land Capability classes is discussed;

(3) Conservation Farm Plans, which embody a scheme of farm management using the most suitable and profitable practices for each individual farm.

Some examples are cited from a conservation survey of the Pohangina district, north-east Manawatu.

Introduction

The passing of the Soil Conservation and Rivers Control Act in 1941 established a Council charged with the promotion of soil conservation, prevention of erosion and damage by flooding, and the utilisation of land in a manner to achieve these objectives. The close relations between land-use and erosion, conservation and flooding, are implicit in the Act. In New Zealand, however, the change from a natural to a cultural landscape (Cumberland, 1941) has been made with little understanding of these relations, though there is a growing recognition of the importance of land-use in catchment and flood control.

To implement effective soil conservation measures, the Soil Conservation and Rivers Control Council has carried out several surveys to establish the causes of erosion and, more important, to provide a basis for planning land-use employing soil conservation principles.

Some Basic Principles

In dealing with erosion, soil conservation and flooding, a most important principle is in the profound effect of different associations of vegetation on the movement of surface and ground water. (Bennett, 1939, Chapter 5). As land-use is reflected in the nature of the vegetative cover, the most potent initial control of water movement is through land and farm management. Also, various plant associations provide different degrees of protection to the soil against erosion. In general, the taller, the more dense, and the deeper rooted the vegetation, the greater the protection against erosion. (Campbell, 1945).

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As soil conservation is concerned with hydrology, the natural unit is the catchment and the whole catchment must be the unit of planning our land resources. Further, to achieve maximum *permanent* production within the unit, land-use must be consistent with both the potential and the natural limitations of each particular piece of land. This is the concept of land capability as developed by the United States Soil Conservation Service. (Bennett, 1939, p. 955).

Farms and paddocks may subdivide catchments. As the application of conservation methods is primarily through farm management, conservation farm plans are drawn up to suit the needs and capabilities of both the farm and the farmer. In this manner maximum permanent production at a profit may be achieved.

The aim is land-use within but not beyond the capability of the soil. Such good land-use is an integrated function using the findings of many branches of scientific investigation—soil science, geology, climatology, agronomy, forestry, farm management, etc. Thus, any practice that helps to keep land productive is a conservation aid. The application of the most suitable combination of practices is necessary to conserve our basic natural resource, the soil.

Types of Surveys

To plan such land-use, a survey of the various factors affecting soil conservation and the present utilisation of land is necessary. Numerous surveys of physical factors such as climate, soils, geology and topography, etc., have been published by government departments. Land utilisation surveys up to 1949 have been grouped by Grange and Smallfield (1949) into those based on present use and those based on suitability for various uses. They proposed a system of land classification based on the system of farming and forestry which the major factors of soil and climatic conditions impose.

In conservation farming, land-use is consciously adjusted to the nature of the land. It is the purpose of soil conservation surveys to examine the nature of the land (Land Inventory Mapping), assess the capability of each area (Land Capability Mapping), and plan land-use on a farm scale (Conservation Farm Plans). The method described is based on the United States Department of Agriculture Soil Conservation Service practice (Hockensmith *et al.*, 1948; Norton, 1939). It has been extended to hill country grazing areas and found suitable for conditions so far encountered. It is suitable for reconnaissance surveys, detailed conservation surveys on a scale of twenty chains to one inch, and conservation farm plans on a scale of five chains to one inch.

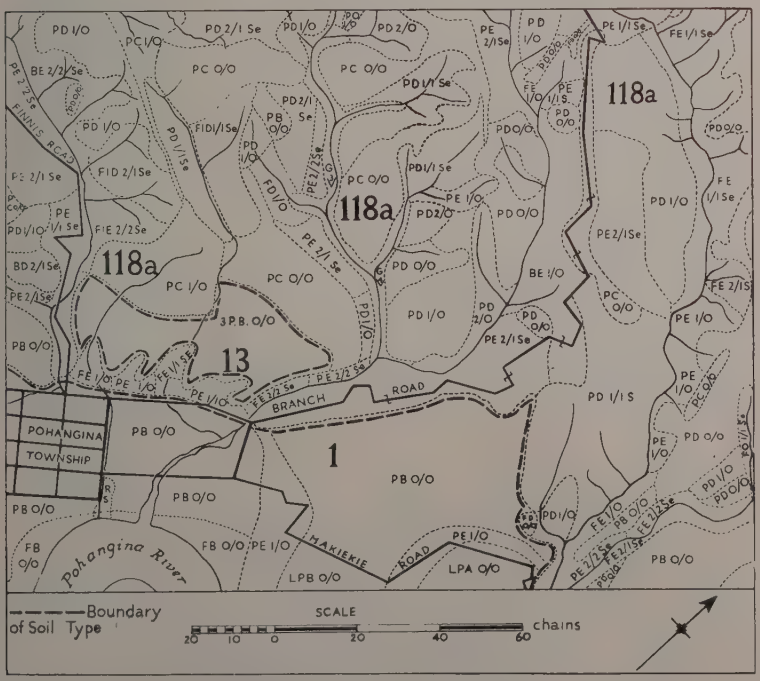
Land Inventory Mapping

To prepare an integrated plan of land use, a technique for obtaining and interpreting knowledge of the factors that affect the use of any piece of land is essential. These factors fall into two main groups. The first group includes the inherent physical factors of the land, such as climate, the nature and distribution of the rocks underlying the area, the nature of the relief and the drainage system, and the soils of the

area. These are largely unalterable characteristics of the landscape. The second group includes the social and economic factors that determine the present pattern of land utilisation.

Land Inventory Mapping is the collecting and recording of all the physical information relevant to the use and conservation of the area being surveyed. In particular, the implications, from a conservation point of view, of climate, geology, soils and vegetation (past and present) are discussed in reports. Whenever possible, these are written by specialists. In addition to these reports there is an analysis of the agriculture of the area, this probably being the most significant report as it aims to ascertain those local practices that enhance stability and those that militate against it. Further, this report reveals the level of farming efficiency. Successful local practice, coupled with up-to-date scientific knowledge, indicates an immediate level of potential development of the land by conservation farming.

Such reports, whilst providing essential information, do not provide a sufficiently concrete or detailed basis for the use of each parcel of land according to its needs and limitations. The use made of any piece of land in an area of similar climate is determined predominantly by the type of soil, the vegetation, the slope of the land and the degree of erosion, if any. These are the factors which, together with the type of erosion, are recorded on the Land Inventory Map (Fig. 1).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The better the knowledge of storm characteristics, droughts and micro-climates, soils, their fertility and mechanics, the distribution of lithologic types with their slope stability characteristics and the protective value of different plant associations, the better will be the Land Inventory Map.

Mapping Method

For field mapping, accurate base maps showing the drainage pattern in detail are required. When available, aerial photographs make the best field sheets. Thorough familiarity with the area enables mapping to be done from stereoscopic examination of aerial photographs, coupled with frequent field checks.

In mapping, the unit area method (Hudson, 1936) is used, the boundary being drawn where there is a significant change in any one of the factors mapped. (Fig. 2).

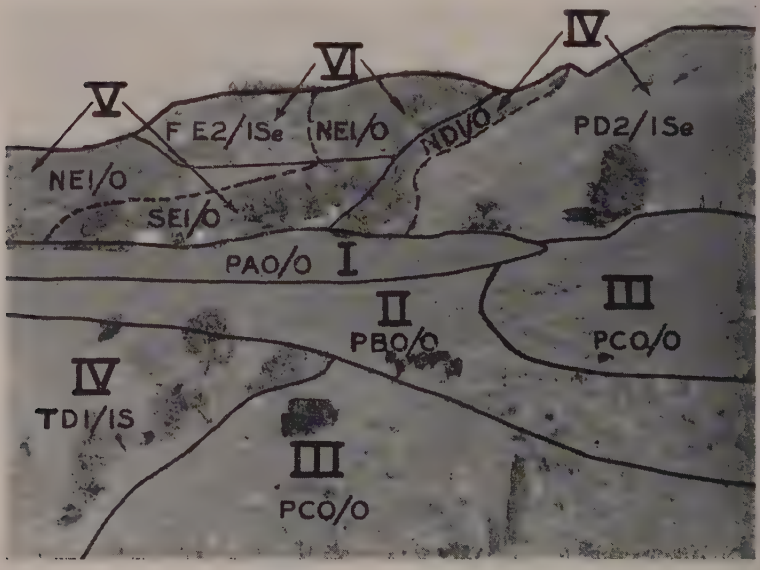

FIG. 2.—A landscape divided into land inventory units (dashed boundary) with their land inventory formulae, and grouped into their appropriate land capability classes from I–IV (solid boundary).

Within each of the enclosed land mapping units are written the symbols representing the soil type, the present vegetation that reflects present land use, the slope group, the extent of erosion and the type of erosion. Together these symbols make up the Land Inventory Formula. (Fig. 1). The order of the symbols is constant so that the position of a symbol in the formula indicates which factor it represents.

Land Inventory Formula

A typical Land Inventory Formula is 118a PD 2/1 Se. This describes an area in the Pohangina district, north-east Manawatu. (Fig. 1). (Greenall *et al.*, 1950). The interpretation of this formula is as follows:—

(a) The first symbol (118a) denotes the soil type. This symbol is the designation given by the Soil Bureau, 118a denoting Pohangina sandy loam. Where a number of adjacent unit areas have the same soil type a dotted line may be drawn around them to enclose a single large soil type symbol. (Fig. 1).

More information on the relative degree of erodibility and permeability of the various soil types is required for detailed soil conservation surveys. Where possible, detailed soil surveys should be completed before conservation surveys are started (Grange, 1944).

(b) The second symbol (P) in the formula denotes the type of the present vegetative cover. Thus cropped areas, pastoral, scrub and bush areas are represented by a different letter symbol. The following are some of the symbols used:—

P	denotes	pasture (types distinguished in agricultural report)
L	„	cropped areas
F	„	scrub and fern
N(F1)	„	native bush
S	„	plantations
T	„	pasture with scattered large trees
t	„	pasture with scattered small trees
B	„	pasture with stumps and logs.

(c) The third symbol (D) denotes the slope group. Five slope groups ranging from Slope Group A to Slope Group E have been used in the present surveys. In general terms, Slope Group A is flat, Slope Group B is gently sloping to undulating, Slope Group C is rolling to moderately steep, Slope Group D is steep and Slope Group E is very steep. In mapping slope groups, the dominant slope, the direction and length of slope, the physical properties of the soil type and the nature of the underlying rocks are considered.

A soil type may occur over a range of slopes. This range of slopes is subdivided into slope groups so that the erodibility of all the soils in one slope group is held to be equal. Thus in any slope group, easily

TABLE I. POHANGINA SURVEY: SLOPE GROUPS

SOIL TYPE	TYPICAL SLOPE RANGE	RANGE OF SLOPES IN EACH SLOPE GROUND A	B	C	D	E
1 MANAWATU LOAM	FLAT, UNDER 5°	0°–5°				
76a KIWITEA LOAM	FLAT TO UNDULATING UNDER 5°	0°–5°				
11 RAUMAI SANDY LOAM	ROLLING 6°–12°	0°–10°	11°–15°	16°–20°	21°–27°	
76aH KIWITEA LOAM (HILLY)	MODERATELY STEEP 13°–23°		8°–13°	14°–24°	25°–32°	33°+over
11H. RAUMAI SANDY LOAM (HILLY)	MODERATELY STEEP 13°–23°		12°–16°	17°–23°	24°–30°	31°+over
118a POHANGINA SANDY LOAM	STEEP & VERY STEEP ABOUT 31°			15°–21°	22°–28°	29°+over

eroded soils will have lower angles of slope than more resistant soils. This is seen in Table I for some soils in the Pohangina area.

There is often a close relationship between the slope groups and the Land Capability Classes. (See below). In the Pohangina survey with certain exceptions, Slope Group A falls into Land Capability Class I, Slope Group B into Land Capability Class II and so on to Slope Group E, which falls into Land Capability Class V or VI. The range of slopes within a slope group is determined by the limit of uses that may be adopted for the particular range of slope. Slope Group B represents the upper limit of slope which may be permanently cropped using special conservation practices as contour cultivation and strip cropping. Slope Group C is the upper limit of slope that is stable without special practices under a dense pasture sward. Slope Group D includes the steepest slopes that remain stable under grass assisted by trees and other conservation practices, as controlled grazing of improved pasture, whilst Slope Group E is too steep to remain stable under any type of grazed grass cover. The range of slopes within each slope group is determined by numerous observations in the field. With increasing local knowledge as the survey progresses the ranges of slope are adjusted until a satisfactory table is produced. A table of slope groups will apply to only one area. Each time a new area is surveyed a new table of slope groups is made out.

(d) The fourth symbol (2/1) in the Land Inventory Formula denotes the extent of erosion. Both figures comprising this symbol may range from 0 to 5. The first figure represents the total area that is eroded, and includes both historical and active erosion. Historical erosion includes any erosion features (not geological) such as slips, slumps and flows that have healed over and are visible on the topographical form. The second figure following the oblique stroke denotes the extent of active erosion at the time of the survey. This compound symbol shows the present state of the land and gives an indication of its erosion potential. For both total erosion and active erosion the figures represent:

0. no significant erosion
1. up to 10% of total area eroded or eroding
2. 11—20% „ „ „ „ „ „
3. 21—40% „ „ „ „ „ „
4. 41—60% „ „ „ „ „ „
5. over 60% „ „ „ „ „ „

(e) The last factor indicated in the Land Inventory Formula is the type or types of active erosion. These are designated by the initial letters of the general type of erosion, e.g., S for slip. The specific type of erosion is mapped by adding a second letter to the general type

letter, e.g., Ss for soil slip. The following is a list of the erosion symbols used, the classification of erosion types following Campbell (1950):

Slip Erosion
- Ss soil slip (affects A and B. horizons of soil)
- Se earth slip (exposes parent material)
- Sr slump (rotational)
- Sc soil creep.

Flow Erosion
- Fl flow erosion undifferentiated
- Fm mud flow
- Fe earth flow
- Fr rock flow
- Fd debris avalanche.

Sheet Erosion
- Sh sheet erosion—wind or water.

Gully Erosion
- G gully erosion.

a. Depth
- G.1. shallow gullies crossable with tillage implements (rills).
- G.2. not crossable with tillage implements, 10 ft. deep.
- G.3. 10 to 25 ft. deep.
- G.4. over 25 ft. deep.

b. Profile
- O underrunners.
- V V-shaped with rapidly eroding bottom.
- U U-shaped with slowly eroding bottom.

Where necessary these profile symbols are added to the depth figure, e.g., G $^{4}/_{V}$ is a gully over 25 ft. deep with a V profile.

River Bank Erosion
- Re river bank erosion.

Accumulations of debris . . . +

Land Inventory Mapping does not record any social or economic factors. Rather it analyses the physical foundations on which permanent and productive utilisation should be based.

LAND CAPABILITY MAPPING

The Land Inventory Map shows physical land mapping units with a coding system describing their main characteristics. An examination of Fig. 1 reveals that classification of the recorded information is necessary in order to better understand and interpret the map. Land Capability Classification is a method of organizing physical land facts in order to plan wise land use. Classification is made by examining land facts together with research results, technical information and successful farm practice.

In the Pohangina survey six Land Capability Classes which fit a broad classification of land use in New Zealand were used (Table II).

TABLE II. LAND CAPABILITY CLASSES

CULTIVATION		PASTURE		FOREST	
I	SUITABLE FOR FREQUENT CULTIVATION	III	SUITABLE FOR HIGH PRODUCING PASTURE	V	SUITABLE FOR PLANTATION OR FARM WOODLOTS
II	SUITABLE FOR OCCASIONAL CULTIVATION OR FOR FREQUENT CULTIVATION WITH SOIL CONSERVATION PRACTICES	IV	SUITABLE FOR PASTURE ONLY WITH SOIL CONSERVATION PRACTICES	VI	SUITABLE FOR PROTECTION FOREST OR FOR RECREATION AND WILD LIFE

The parcels of land separated and defined on the Land Inventory Map were placed in one or other of these six Land Capability Classes. A decision concerning the Land Capability Class in which a parcel of land should be placed, is governed by the actual or potential fertility of the land, the types of vegetation that would flourish, and the limitations to use imposed by slope or erosion. It is the maximum intensity of safe use that determines the class in which a parcel of land is placed. For instance, a flat fertile well-drained soil could be used for any normal purpose from intensive cropping on the one extreme to trees at the other, and would be placed in Class I. On the other hand a shallow infertile soil, on a steep slope overlying unstable sand substrata would have its safe use restricted to trees and would be placed in Class VI.

Classification of parcels of land could be done one by one, but is considerably speeded up and made more uniform by grading the factors according to kind and degree.

The factors mapped are arranged in decreasing order of influence on land use, e.g., in Pohangina the order would be soil type, slope group, extent of erosion and type of erosion.

As explained before, the soils are arranged into five slope groups of increasing susceptibility to erosion from Group I to Group V (Table I).

Table III shows the divisions of increasing severity of erosion, based on the type and severity of erosion and its effect on run-off and production.

TABLE III. RATING OF EROSION SEVERITY

NO EROSION	SLIGHT	MODERATE	SEVERE	VERY SEVERE
0/0	1/0	2/1 Se	3/2 SeFl	G 3 – 4
	1/1	2/2 Se	3/3 Se	G① – ④
	2/0	3/1 Se	3/3 SeFl	G⑴ – ⑷
		3/2 Se	G 1–2	G⑴ – ④

Tables I and III are then combined to form one table (Table IV) showing the slope groups and erosion characterising Land Capability Classes. The placing of the symbols in their respective Land Capability Class is based on the best judgement of the land capability mapper. In practice, slope group and erosion severity classes are drawn up early in the survey. A tentative grouping of these into Land Capability Classes is then made. As the survey progresses and further evidence, knowledge and observations are acquired, adjustments are made to the initial groupings.

TABLE IV. POHANGINA SURVEY: SLOPE GROUPS AND EROSION CHARACTERIZING LAND CAPABILITY CLASSES

SOIL TYPES	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V
1. MANAWATU LOAM 2. KAIRANGA SILT LOAM 76b. RANGITIKEI SILT LOAM 76a. KIWITEA LOAM	A 0/0	B 0/0	C 0/0		
11. RAUMAI SANDY LOAM 13b. PIRONIA SANDY SILT LOAM		B 0/0	C 0/0 C1/1Se C 1/0 C2/1Se	D0/0 D1/1Se D 1/0 D2/1Se	
76aH. KIWITEA LOAM (HILLY) 29 H. OMAKERE SILT LOAM (HILLY)		B 0/0	C 0/0. C1/1SeFl C 1/0. C3/1SeFl C 1/1S	D0/0. D2/1Se D1/0. D2/2Se D1/1S D3/3SeFl	E1/0 E3/3 Se E1/1Se G⑶-⑷ E2/0 G⑶-⑷ E2/1Se E2/2Se
11H. RAUMAI SANDY LOAM (HILLY)		B 0/0	C 0/0 C 1/0 C 1/1Se	D0/0. D1/1Se D1/0. D2/2Se	E1/0 E2/2Se E1/1Se G⑶-⑷ E2/1Se G⑶-⑷ E2/1Se
118a. POHANGINA SANDY LOAM			C 0/0 C 1/0 C1/1Se C3/1SeFl	D0/0 D2/2Se D1/0 D3/1Se D1/1Se D3/2Se D2/0	E1/0 E2/2Se E1/1SeE3/2Se E2/0. G⑶-⑷ E2/1Se G⑶-⑷

From this table of slope groups and erosion characterising Land Capability Classes, the various parcels of land on the Land Inventory Map are allotted to their appropriate Land Capability Class. Any regional differences between land in the same class are provided for by appropriate subdivisions of a class. Using the Land Inventory Map as a base, the Land Capability Classes are delineated (in colours) to form the Land Capability Map. (Fig. 3).

A general description of the land in each of these classes in the Pohangina district is:—(Fig. 2 and 3):

Class I: Good flat to gently undulating land that can be frequently cropped provided good soil and fertility maintenance practices are used; no special soil conservation practices are needed; while cereal crops can be grown satisfactorily, the climate renders harvesting slightly risky; forage crops are the most suitable and do very well.

Class II: Potentially good flat land that requires draining, or stumping, or removal of rocks to make cultivation possible; flat land that has an associated gully, siltation or flooding factor;

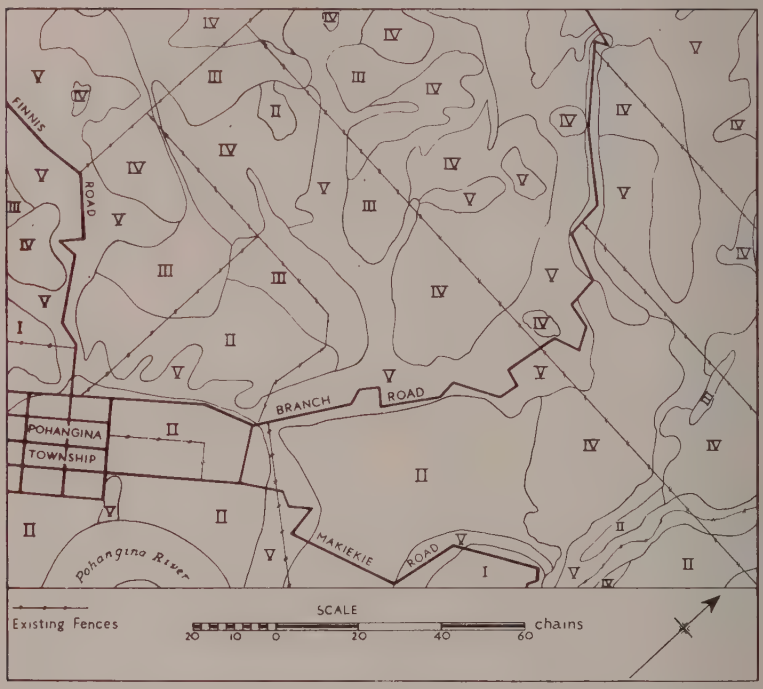

FIG. 3.—Land Capability Map of Portion of Watershed of Pohangina River.

rolling land that can be infrequently cropped without special conservation practices; rolling land that is suitable for frequent cultivation only with special conservation practices.

Class III: Land that is not suitable for cultivation, but very suitable for permanent high producing pasture; it is strongly rolling to moderately steep, and relatively stable under present district pasture management practices; however, it requires controlled grazing, topdressing and oversowing with clovers to make it fully productive and stable, and to reduce the run-off.

Class IV: Moderately steep to steep land that is not suitable for cultivation. It is suitable for permanent pasture only with:—

(a) Space planting of trees;

(b) Controlled lax grazing with adequate subdivision as well as the fencing of sunny from dark faces;

(c) Pasture improvement with topdressing and oversowing with suitable clovers;

(d) Vegetative and mechanical treatment of local slipped, slumped and gullied areas.

Class V: Steep to very steep and precipitous land that requires urgent treatment; a portion of this area requires intensive space

planting, or improvement of vegetative cover by controlled lax grazing, mainly with cattle; a further portion that is accessible to track or road should be planted to farm woodlots and plantations.

Class VI: Land that should be retired from grazing to revert to scrub, fern, and native bush; this class consists mainly of canyons and the very steep sides and hill slopes above these.

The management of each of these classes should be explained fully in a technical report. Particular emphasis is given in this to regional or district characteristics and problems and their relation to soil conservation. Possible alternative practices, modifications of present practice and the application of soil conservation and scientific findings to the local problem are discussed, where possible, with the farmers and specialists concerned.

New knowledge, experience, the success or failure of new or old techniques, may ultimately necessitate a change in the farm management descriptions, or even a change in classifications of some parcels of land.

With further surveys, it has become apparent that certain areas do not fit easily into a six-fold land classification. After considerable experience, the United States Soil Conservation Service has built up an eight-fold land classification (Hockensmith, 1947, pp. 13-14) and this has recently been adopted as a basis for further work in New Zealand.

The following is a brief description of these Land Capability Classes:—

Land Suitable for Cultivation

Class I. Very good land that can be cultivated with ordinary good farming methods.

Class II. Good land that can be cultivated safely with easily applied practices, as contour cultivation.

Class III. Moderately good land that can be cultivated safely only with intensive treatments, such as terracing and strip cropping.

Land Suited for Limited Cultivation

Class IV. Fairly good land that is best suited to pasture and hay; can be cultivated occasionally, usually not for more than one year in six.

Land Not Suited for Cultivation

Class V. Suited for grazing or forestry with slight or no modifications; needs only ordinary good management as it is nearly level and not subject to erosion; it cannot be cultivated because it is wet, rocky, or stumps are present.

Class VI. Suited for grazing or forestry with minor limitations and protective measures; moderately sloping land that is subject to wind or water erosion.

Class VII. Suited for grazing or forestry with major limitations, requiring extreme care to prevent erosion; steep land that is eroding or highly susceptible to erosion.

Class VIII. Suited only for native vegetation and reserves.

Conservation Farm Plans

The division of the area into Land Capability Classes provides a general plan of improved land use. To be effective this plan must be applied on the unit holdings comprising the catchment.

As individual farmers adopt the scheme, a detailed Conservation Farm Plan is prepared by a soil conservator and the farmer concerned. Expert advisers are consulted when necessary. Such a farm plan is based on an intimate practical knowledge of each farm and the most suitable agricultural techniques.

A plan of the farm is drawn up on a scale of five chains to one inch. The Land Capability Class boundaries are defined in greater detail than on the Land Capability Map. The relative areas of the various capability classes, existing fence lines and farmer preference are considered when the plan is drawn up so that suitable farming units are formed. This is usually a long term plan in which major modifications, such as re-alignment of fences, take place gradually and, where possible, are within the resources of the farmer. The crops or stock that give the greatest profit are selected provided they suit the capabilities of both the farm and the farmer.

The plan must be dynamic in order to absorb new knowledge and experience and to meet changing economic and social conditions. This ensures continued profitable management of each farm as a permanent productive unit.

Discussion

Previous investigations have established the seriousness of the problem of actual or potential loss of production due to erosion. Correct land use is undoubtedly the most effective control measure.

Land use is a problem of land and people. The continued wellbeing of both land and people depends on understanding, acceptance and action founded on sound concepts. One such concept is that land has inherent factors which dictate the limit of safe use of land. This has previously been either imperfectly understood or the attraction of high production for the greatest profit has claimed more attention. Land use must be within the range dictated by the physical limitations of land if it is to remain permanently productive. Conservation farm plans arising from the Land Capability Mapping method fully recognise this concept.

No matter how good a plan is, it is valueless unless used. Before a farmer will adopt a plan its advantages must be recognized and it must be practical and readily applicable on a farm scale. The plan

derived from these surveys meets with these requirements, and may be applied by any farmer with ultimate achievement of the maximum safe production potential of the soils.

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PASTURE ESTABLISHMENT STUDIES

I. THE EFFECT OF GRASS SEEDING RATE ON THE ESTABLISHMENT AND DEVELOPMENT OF PASTURES OF SHORT ROTATION RYEGRASS, RED AND WHITE CLOVERS

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Summary

Pastures were sown in the autumn with seven seeds mixtures which contained different amounts of short rotation ryegrass seed per acre, but constant amounts of red and white clovers. Herbage yields were measured over a period of 12 months; seedling populations were counted and plant development was measured.

For the winter period, yield of dry matter showed linear relationships with ryegrass seeding rate. The total herbage yield and also the yield from ryegrass increased with increase in seeding rate, whereas the yield from clovers decreased.

For the spring period, ryegrass yields were lowest at the high seeding rates, and in the late spring there was a trend towards depression in ryegrass yield at the intermediate rates also.

Over the summer period, yields were similar for all treatments, except that clover yields at intermediate seeding rates were higher than at extreme rates.

At low seeding rates, clovers developed rapidly and yielded well. At high seeding rates, clovers were initially suppressed, but their development and yield improved whenever ryegrass yield declined.

The results are discussed in terms of competition for light within and between species, and later for nitrogen at the higher seeding rates.

Introduction

In the establishment of pastures, competition both between and within species occurs, and in New Zealand, where the species sown are generally ryegrasses and clovers, the aggressive species, particularly in autumn sowings, are the ryegrasses. Of recent years there has been a trend towards the increased use of short rotation ryegrass (*Lolium perene x L. multiflorum*), either as the only grass species in the mixture or in association with perennial ryegrass (*L. perenne*). Short rotation ryegrass grows more vigorously in winter than does perennial ryegrass (Corkill, 1945) and its seedling growth rate is also greater (Mitchell, 1953). Consequently its competitive effect on the relatively slow growing clovers is greater than that of perennial ryegrass. When short rotation ryegrass is sown with red clover (*Trifolium pratense*) and white clover (*T. repens*), indifferent establishment of the clovers often occurs, and the development of every species in the pasture is then adversely affected.

The aggressiveness of ryegrass in autumn-sown pastures during the establishment stage may be lessened by reducing the seeding rate, by frequent grazing, or by purposely reducing the level of soil nitrogen of the area to be sown. The influence of grazing is dealt with in Part

II of this series; the effect of different levels of soil nitrogen on pasture establishment has recently been demonstrated by Sears (1953a).

By reducing the seeding rate of the aggressive species in pasture mixtures, both intra-species and inter-species competition is lessened, and better development of sown species is obtained. Donald (1951), in a detailed investigation of the influence of plant density, stage of growth, and soil fertility on intra-species competition among annual pasture plants, concluded "that in dense populations, competition is evident shortly after germination and thereafter becomes operative progressively in populations of lower and lower density." The species studied were Wimmera ryegrass (*L. loliaceum*) sown at rates between 7 oz. and 1,400 lb. per acre and subterranean clover (*T. subterraneum*) at rates from 6 oz. to 1,800 lb. per acre. For the grass species, Donald suggested that competition was primarily for nitrogen, and for the clover species, for light. Williams (1947), working under controlled conditions, demonstrated the effects of seeding rate of ryegrass on the growth of individual plants in a ryegrass-red clover association, for a period of 14 weeks from sowing. The range of rates studied were 1–14 lb. per acre and the results showed increased percentage emergence and better growth of individual ryegrass and clover plants at the lower seeding rates. Hughes and Davis (1951), investigating the development of swards sown with perennial ryegrass at 6 and 18 lb. per acre, with white clover at 4 lb. per acre and cocksfoot-white clover mixtures sown at the same rates, found little difference in dry matter and crude protein yields in ryegrass mixtures due to rate of seeding. This applied for three annual harvest periods from sowing. Similar results to these were also obtained by Rasmussen (1936).

In view of the above findings, an experiment was laid down to determine whether in a mixed pasture of short rotation ryegrass and red and white clover, more successful establishment of sown species could be obtained by suitably adjusting the rate of sowing of the short rotation ryegrass. To this end it was planned to study the influence of ryegrass seeding rate on the productivity of the developing pasture, the contribution of the different species to the total herbage yield, and the development of the individual pasture plants.

Experimental Design and Procedure

The experimental area was at Palmerston North and before ploughing in March 1952 was of relatively high fertility, having been in spaced ryegrass plants, fertilised with superphosphate and sulphate of ammonia, and grazed by sheep. After ploughing and seed-bed preparation, the area was topdressed with 3 cwt. of superphosphate per acre. Short rotation ryegrass was sown at the following rates: 0, 10, 15, 20, 30, 40 and 60 lb. per acre. These comprised the seven treatments applied in the experiment. In each plot red and white clover were sown at constant rates of 4 lb. and 3 lb. per acre respectively. All seeds sown were of pedigree origin and all rates were pounds of viable seed per acre. The seven treatments were replicated four times in randomized blocks, each plot being 8 ft. x 20 ft.

The plots were hand-sown and, to obtain uniform distribution, individual mixtures were diluted with a quantity of sawdust. This

enabled three or four complete dressings of each plot to be made. After sowing the plots were hand-raked.

The plots were grazed by sheep, and for the first three grazings the herbage height was about 3–4 in. All other grazings took place when the herbage height was about 6 in. The only deviation from this procedure occurred at the first two grazings. The young plants in the lower seeding rate plots adopted a more prostrate habit of growth and the herbage height at the first grazing was about 2–3 in. This effect was still apparent at the second grazing, but to a lesser degree.

Before each grazing, a 2-ft. strip of herbage was mown lengthwise through each plot. The plot width permitted the cutting of three such strips at successive grazings, so that each part of a plot had two successive grazings followed by a mowing, and so on. The herbage cut was weighed, and samples were taken for percentage dry matter determinations and botanical analyses. The remainder was fed to the sheep grazing the plots. Harnessed wethers were used for all grazings and the dung and urine collected, using the technique outlined by Sears (1944), was returned, at the conclusion of each grazing, to each plot in proportion to its yield.

Seedling counts were made at emergence, and at intervals during the experiment, counts were made of clover plants and ryegrass tillers, and tiller weights were obtained. For the emergence counts and clover-survival counts, a quadrat 3 ft. by 4 in. was used, and sequential random samples sufficient to give statistical accuracy were taken. Ryegrass tiller numbers were obtained by cutting a square foot sample of herbage to ground level. The tillers obtained were oven dried and weighed.

The trial was concluded on 9 April 1953.

Results

Total Herbage Production and Species Yields

Yields are presented for three periods. The first period comprises late autumn, winter, and early spring, during which the dominant component of the establishing pastures was ryegrass. The second comprises spring and early summer, when the influence of the clover components on total herbage and ryegrass yields became effective, and the third comprises summer and early autumn, during which yields obtained from ryegrass and clover were in approximately equal proportions.

Finally, the results for the whole experimental period are given.

In Tables I–IV there are shown for each period total herbage yields and also the yields of separate species. Yields are expressed throughout as pounds of D. M. per acre. Analyses of variance were performed on total herbage, ryegrass and clover (red and white clover combined) yields, and these were then extended to test the relationship between Treatments 2–7 (i.e., omitting the basic clover Treatment 1). The graphs of these relationships are shown in Figs. 1–4.

In the regression analyses appended to each table, "Linear Term" tests the linearity of simple trend in the data, "Quadratic Term" tests the significance of the curvature of the data, and "Cubic and Higher Terms" tests whether higher order curves than the quadratic should be used to specify the data.

There was only one case in which a curve of higher order than the quadratic would have given a significantly better fit to the data, although in another case significance is obtained at the 10 per cent level of probability. In this case, the abnormal behaviour of Treatment 6 affected the yields. In laying down the experiment, individual plots of each replication were placed in such a manner that the length of each plot was in the same direction as the ploughed furrow. By chance, two plots of Treatment 6 coincided with the finish of ploughing and the method of ploughing was such that a depression occurred along this finish. Although filled by levelling during the preparation of the area, the depression was still apparent after consolidation.

TABLE I. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR FIRST PERIOD (1.4.52—22.9.52)

Treatment Number	Rate of Ryegrass Sowing (lb./ac.)	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
			Ryegrass	Clovers			Unsown Species
				Red	White	Total	
1	0	1490	70	200	330	530	890
2	10	1890	1260	120	220	340	290
3	15	2100	1530	100	180	280	290
4	20	2220	1690	80	170	250	280
5	30	2430	2090	70	130	200	140
6	40	2290	1900	70	130	200	190
7	60	2760	2520	50	60	110	130
Standard Errors		±100.1	±101.0			±42.3	

REGRESSION ANALYSES FOR TABLE I (1st PERIOD)

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	3							
Linear Term	1	4.54 (8.68)	3,507,035	95.900**	117,430	25.90**	1,534,408	38.33**
Quadratic Term	1	4.54 (8.68)	41,862	1.03—	2,066	0.46—	6,586	0.16—
Cubic and Higher Terms	3	3.29 (5.43)	135,500	3.32*	2,272	0.50—	80,187	2.00—
Residual	15		40,806		4,534		40,035	

** significant at the 1% level of probability
*Significant at the 5% level of probability
— differences not significant

The area consequently drained to the depression and water after heavy rains lay for periods up to 48 hr. The effect of this on growth, and particularly on ryegrass growth, during the winter period, is shown in a number of the tables and figures presented, particularly Table I, where ryegrass yields for Treatment 6 are lower than those for Treatment 5. However, adjustments to the data by fitting constants for trends across the layout gave little worthwhile improvement in smoothing the data and were not used further.

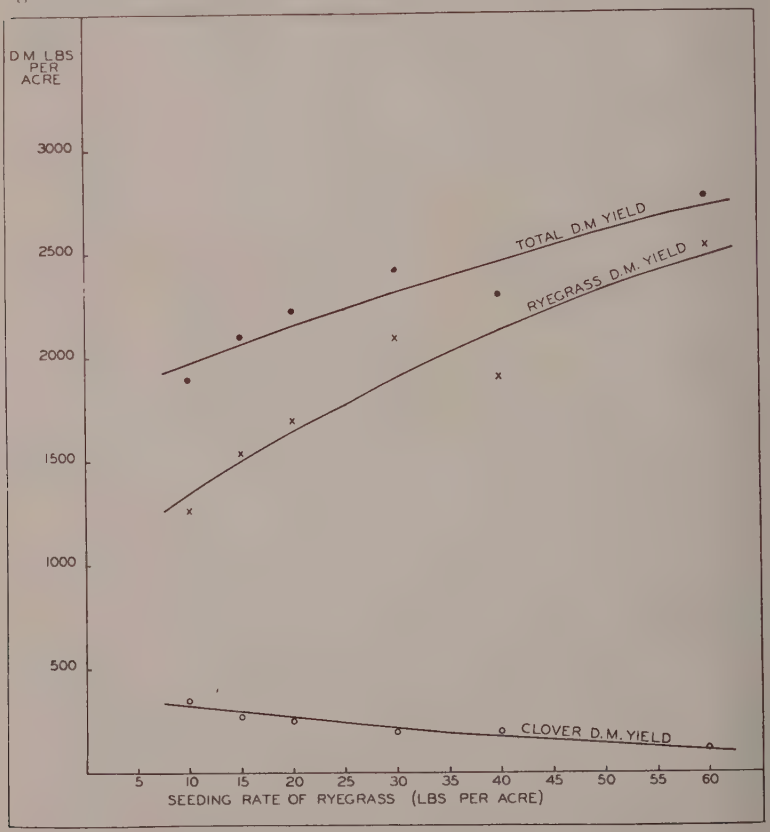

FIG. 1.—Relationships between Total and Species Yields and Seeding Rate of Short Rotation Ryegrass for the 1st Period.

First Period (1.4.52–22.9.52)

Table I gives the total and species yields of the seven treatments.

The following deductions are made from Table I.

(1) *Ryegrass*: There was a highly significant *upward* trend, with no significant curvature, for ryegrass yield with increasing seeding rate, i.e. increase in yield was proportional to increase of seeding rate.

(2) *Clover*: There was a highly significant *downward* trend, with no significant curvature, for total clover yield with increasing ryegrass seeding rate, i.e. decrease in clover yield was proportional to increase of ryegrass seeding rate.

(3) *Unsown Species*: Statistical analyses of the D.M. yields from unsown species were not made. However, the results obtained, as shown in Table I, indicate that yield from these species decreased in proportion to increase of ryegrass seeding rate.

(4) *Total*: There was a highly significant *upward* trend, with no significant curvature, for total production with increasing ryegrass seeding rate, i.e. increase in yield was proportional to increase in ryegrass seeding rate.

Second Period (22.9.52–5.1.53)

Table II gives the total and species yields of the seven treatments.

TABLE II. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR SECOND PERIOD (22.9.52—5.1.53)

Treatment Number	Rate of Ryegrass Sowing (lb./ac.)	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
			Ryegrass	Clovers			Unsown Species
				Red	White	Total	
1	0	5010	620	790	1620	2410	1980
2	10	6280	4820	460	740	1200	260
3	15	6280	5180	400	515	915	185
4	20	6430	5430	325	470	795	205
5	30	6290	5480	375	345	720	90
6	40	6120	5230	305	480	785	105
7	60	5800	4970	240	485	725	105
Standard Errors		±172.9	±182.2			±66.1	

REGRESSION ANALYSES FOR TABLE II (2nd PERIOD)

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	3							
Linear Term	1	4.54 (8.68)	4,927	0.04—	312,082	19.95**	748,890	5.07*
Quadratic Term	1	4.54 (8.68)	958,011	7.21*	185,502	11.86**	127,745	0.87—
Cubic and Higher Terms	3	3.29 (5.43)	117,072	0.88—	51,274	3.28(*)	28,754	0.19—
Residual	15		132,827		15,642		147,629	

** Significant at the 1% level of probability
* Significant at the 5% level of probability
(*) almost significant at the 5% level of probability
— differences not significant

The following deductions are made from Table II:

(1) *Ryegrass*: There was a significant curved regression for ryegrass yield on seeding rate.

(2) *Clover*: There was a highly significant curved regression for total clover yield on ryegrass seeding rate.

(3) *Unsown Species*: The data in Table II indicates an inverse relationship between yield of unsown species and ryegrass seeding rate, with largest yields at the lightest seeding rates. This data was not analysed statistically.

(4) *Total*: There was a significant downward trend, with no significant curvature for total yield with increasing ryegrass seeding rate.

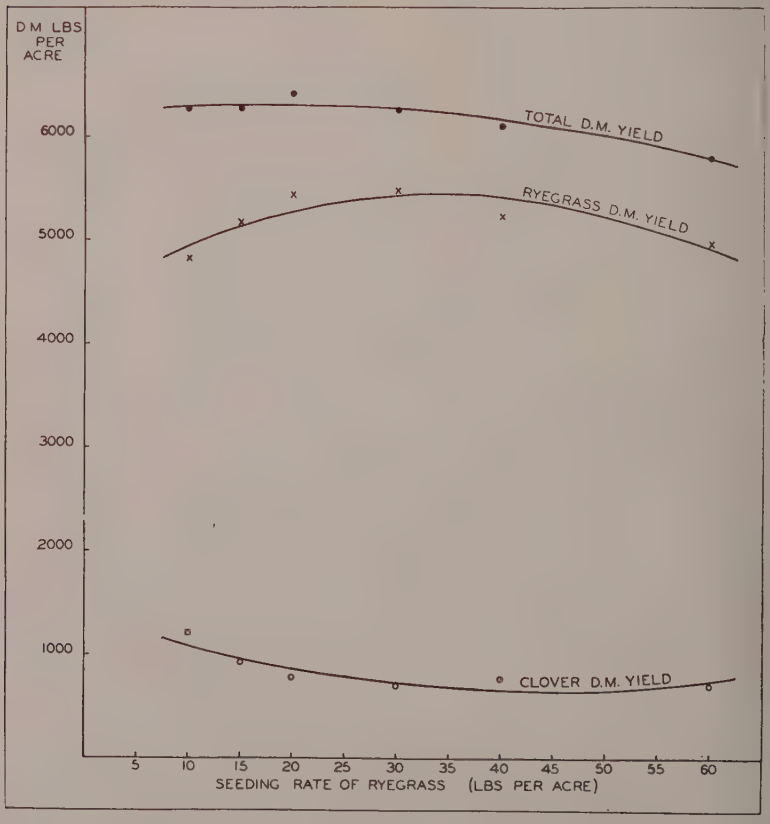

FIG. 2.—Relationships between Total and Species Yields and Seeding Rate of Short Rotation Ryegrass for the 2nd Period.

Third Period (5.1.53–9.4.53)

Table III gives the total and species D.M. yields of the seven treatments.

TABLE III. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR THIRD PERIOD (5.1.53—9.4.53)

Treatment Number	Rate of Ryegrass Sowing (lb./ac.)	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
			Ryegrass	Clovers			Unsown Species
				Red	White	Total	
1	0	3310	350	510	1910	2420	540
2	10	3850	2240	500	1050	1550	60
3	15	3780	2070	545	1095	1640	70
4	20	3810	2100	610	1040	1650	60
5	30	3780	2020	750	980	1730	30
6	40	3780	2000	705	1055	1760	20
7	60	3600	2150	405	995	1400	50
Standard Errors		±128.0	±121.0			±80.1	

REGRESSION ANALYSES FOR TABLE III (3rd PERIOD)

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	3							
Linear Term	1	4.54 (8.68)	7,802	0.13—	43,896	1.50—	120,444	1.73—
Quadratic Term	1	4.54 (8.68)	130,312	2.22—	287,138	9.81**	13,549	0.19—
Cubic and Higher Terms	3	3.29 (5.43)	8,916	0.15—	20,741	0.71—	5,676	0.08—
Residual	15		58,612		29,269		69,615	

** Significant at the 1% level of probability
— differences not significant

Deductions from Table III are:

(1) *Ryegrass*: The trend in the relationship between ryegrass yield and seeding rate did not reach significance level, i.e. ryegrass yields from Treatments 2–7 did not differ significantly.

(2) *Clover*: There was a highly significant curved regression for clover yield on ryegrass seeding rate.

(3) *Unsown Species*: Yields from unsown species were a negligible part of the total yields, as shown in Table III.

(4) *Total*: There was no significant trend in the relationship between total yield and ryegrass seeding rate, i.e. total yields from Treatments 2–7 did not differ significantly.

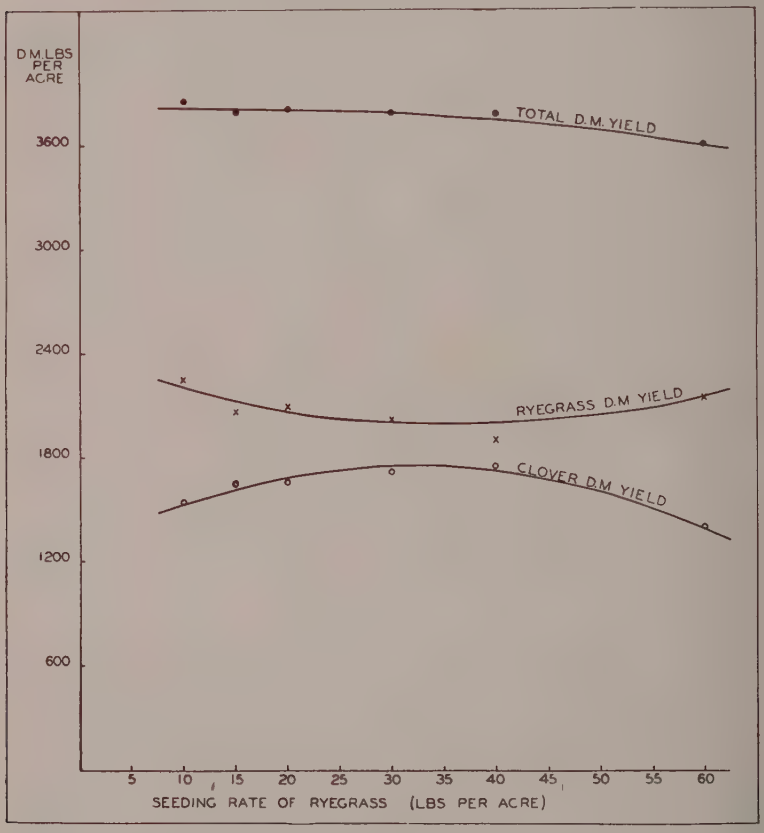

FIG. 3.—Relationships between Total and Species Yields and Seeding Rate of Short Rotation Ryegrass for the 3rd Period.

Total Period (1.4.52–9.4.53)

Table IV gives the total and species D.M. yields of the seven treatments.

Deductions from Table IV are:

(1) *Ryegrass*: There was a significant *upward* trend, with almost significant curvature, for ryegrass yield with increasing seeding rate.

(2) *Clover*: There was a highly significant *downward* trend, with no significant curvature, for total clover yield with increasing ryegrass seeding rate, i.e. decrease in total clover yield was proportional to increase in ryegrass seeding rate.

(3) *Unsown Species*: Although not analysed statistically, Table IV shows higher yields from unsown species at the lower ryegrass seeding rates.

(4) *Total*: There was no significant trend in the relationship between total yield and ryegrass seeding rate, i.e. for Treatments 2–7 inclusive the total yields obtained for the full period of the trial did not differ significantly.

TABLE IV. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR TOTAL PERIOD (1.4.52—9.4.53)

Treatment Number	Rate of Ryegrass Sowing (lb./ac.)	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
			Ryegrass	Clovers			Unsown Species
				Red	White	Total	
1	0	9810	1040	1500	3860	5360	3410
2	10	12020	8320	1080	2010	3090	610
3	15	12160	8780	1045	1790	2835	545
4	20	12460	9220	1015	1680	2695	545
5	30	12500	9590	1195	1455	2650	260
6	40	12190	9130	1080	1665	2745	315
7	60	12160	9640	695	1540	2235	285
Standard Errors		±257.8	±225.8			±120.2	

REGRESSION ANALYSES FOR TABLE IV (TOTAL PERIOD)

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	3							
Linear Term	1	4.54 (8.68)	2,938,031	14.40**	1,233,962	19.63**	744	0.00—
Quadratic Term	1	4.54 (8.68)	622,440	3.05—	2,520	0.04—	350,849	1.58—
Cubic and Higher Terms	3	3.29 (5.43)	468,545	2.30—	104,442	1.66—	120,584	0.54—
Residual	15		203,992		62,871		222,551	

** Significant at the 1% level of probability
— differences not significant

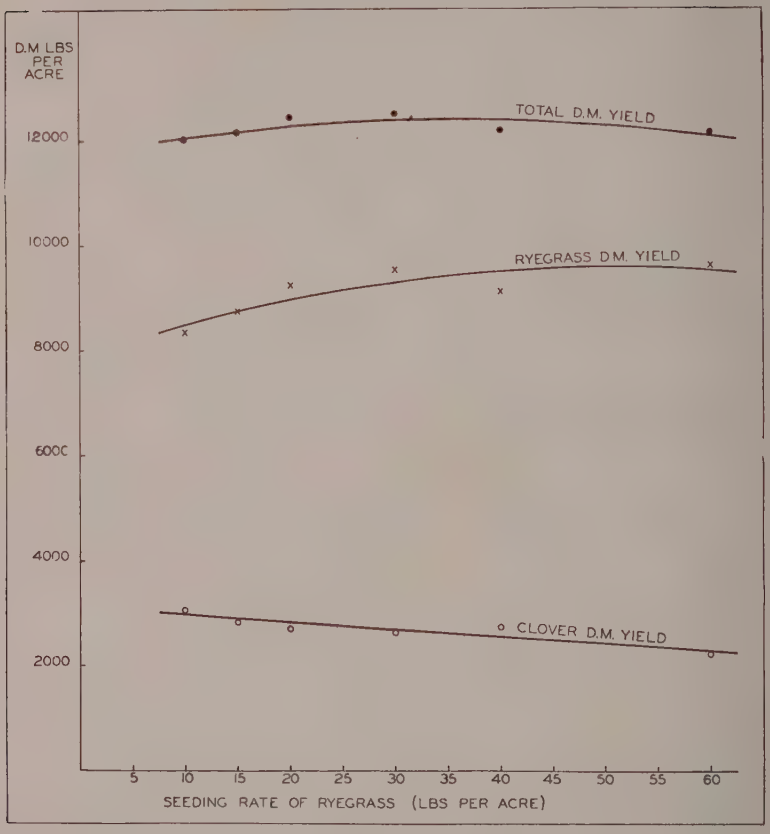

FIG. 4.—Relationships between Total and Species Yields and Seeding Rate of Short Rotation Ryegrass for the full Period.

Percentage Emergence and Tiller Development of Short Rotation Ryegrass

Table V shows initial ryegrass emergence counts given, both as number of emerged seedlings per unit area, and as percentage emergence of viable seeds sown for each sowing rate. Also shown are two subsequent determinations of tiller numbers per unit area and dry weights per 100 tillers. The results of analysis of variance for each are included.

Estimates of the mean numbers of tillers per plant were obtained by dividing number of tillers per sq. ft. by the count of emerged seedlings. No account was taken of possible seedling or tiller death.

The relationships between ryegrass seeding rate and mean number of tillers per plant were determined by a modified form of the analysis of variance. Table VI shows the regression analyses for both counts.

TABLE V. RYEGRASS EMERGENCE, TILLER NUMBERS PER UNIT AREA AND DRY WEIGHTS (in grams) PER 100 TILLERS

	Results at Seeding-rates indicated							
	10 lb./ ac.	15 lb./ ac.	20 lb./ ac.	30 lb./ ac.	40 lb./ ac.	60 lb./ ac.	Results of F Tests	d.05 (where F Sig.)
Viable seeds sown per sq. ft. (2.4.52)	47.8	71.7	95.6	143.4	191.2	286.8	—	
Emerged Seedlings per sq. ft. (4.5.52)	33.4	46.6	61.2	91.5	119.8	184.2	**	23.1
Percentage Emergence of Viable Seeds Sown	70.0	65.0	64.0	63.8	62.7	64.2	—	
Number of Tillers per sq. ft. (18.8.52)	306	303	342	403	403	476	**	80.1
Dry Weight (g) of 100 Tillers (18.8.52)	3.20	2.90	2.61	2.98	2.70	2.81	—	
Number of Tillers per sq. ft. (20.10.52)	442	436	461	498	568	634	*	119.7
Dry Weight (g) of 100 Tillers (20.10.52)	5.39	5.12	4.91	4.14	4.01	3.51	**	0.79

d.05 difference detectable at 5% level of probability
** significant at the 1% level of probability
* significant at the 5% level of probability
— no significant differences

TABLE VI. REGRESSION ANALYSES TO SHOW THE RELATIONSHIP OF TILLERS PRODUCED PER EMERGED SEEDLING AND SEEDING RATE

Source of Variation	d.f.	F Reqd. 5% (1%)	Count on 18/8/52		Count on 20/10/52	
			Mean Sq.	F	Mean Sq.	F
Linear Regression of Tillers per Emerged Seedling on Seeding Rate	1	4.54 (8.68)	93.64	83.81**	140.52	26.22**
Departures from Linear Regression	4	3.06 (4.89)	5.74	5.14**	31.09	5.80**
Residual	15		1.12		5.36	

** significant at the 1% level of probability

Deductions from Tables V and VI are:

For both counts there was a highly significant downward curved regression of tillers produced per emerged seedling on ryegrass seeding rate.

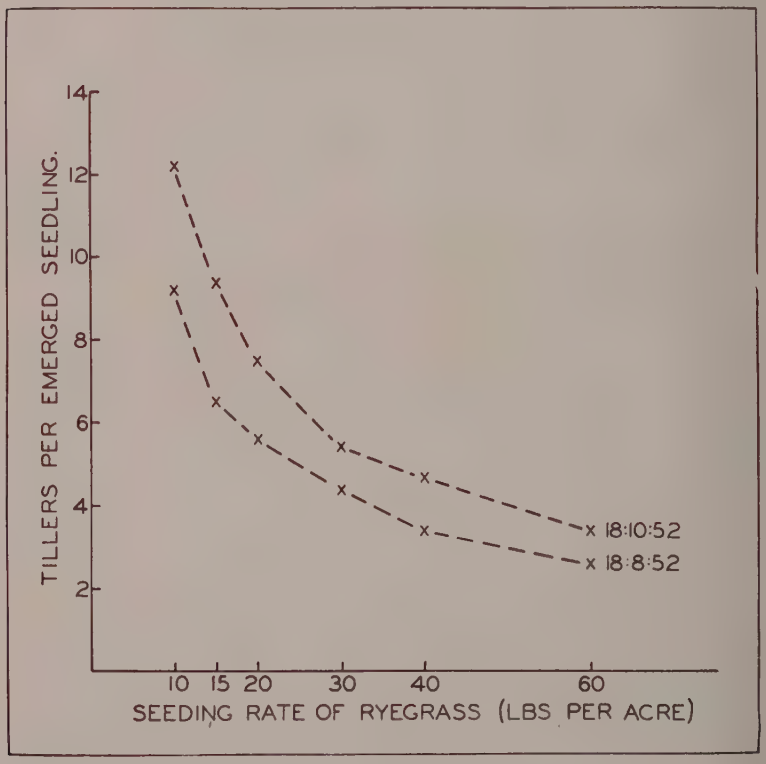

FIG. 5.—Relationships of Tillers per Ryegrass Plant and Seeding Rate of Short Rotation Ryegrass on the Dates Shown.

Dry Weights per 100 tillers, associated with the above counts of tiller numbers, were similarly tested for regressions of tiller dry weight on seeding rate. For the first weighings, the test gave no significant relationship, but for the second weighings a highly significant downward linear trend of tiller dry weight with increasing ryegrass seeding rate was obtained ($F = 36.0$, d.f. (1, 15)). Fig. 6 shows the data and curves for both weighings.

Percentage Emergence and Plant Survival of Red and White Clover

Table VII shows emergence counts of red and white clover, both as number of seedlings per sq. ft., and as percentages of viable seeds

sown, together with one subsequent determination of the number of surviving red and white clover plants. Results of the analyses of variance for each count are included.

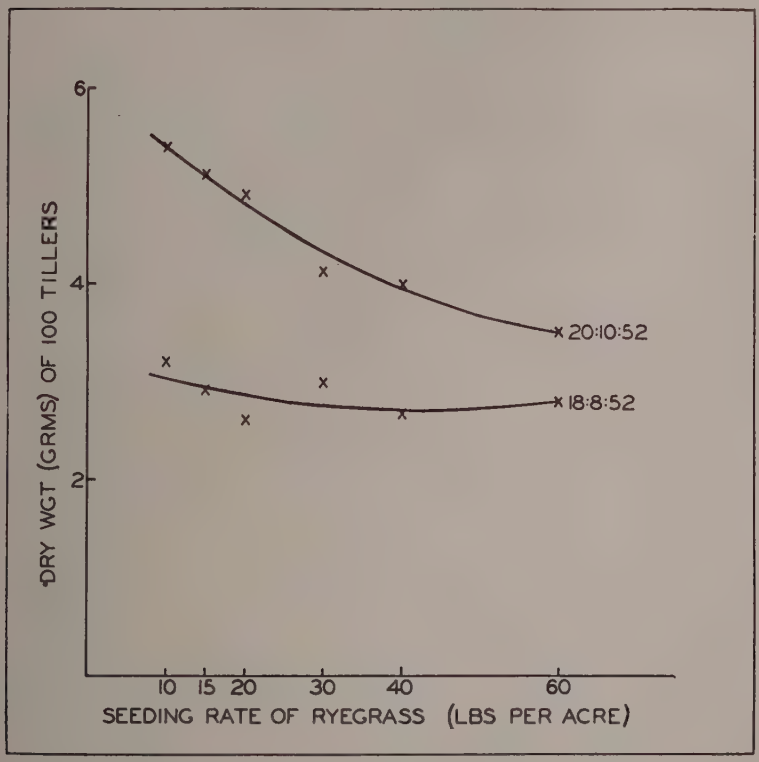

FIG. 6.—Relationships of Tiller Dry Weight and Seeding Rate of Short Rotation Ryegrass on the Dates Shown.

The table shows significant differences between the percentages of red and white clover seeds emerging. For this reason analyses of covariance were required for both species of plants surviving on 16.9.52, using initial counts of emerged seedlings as concomitant information. The relationship between the numbers of surviving clover plants and ryegrass seeding rate were then examined by regression analyses of adjusted plant survival means.

Deductions from Tables VII and VIII are:

Red Clover: There was a highly significant downward curved regression of numbers of surviving red clover plants on ryegrass seeding rate.

White Clover: There was a highly significant downward curved regression of numbers of surviving white clover plants on ryegrass seeding rate. (The analysis also shows that there were significant deviations from the fitted curve and simply states the irregularity of the data.)

TABLE VII. EMERGENCE COUNTS OF RED AND WHITE CLOVER (as number of emerged seedlings per sq. ft. and as percentage emergence of viable seeds shown) AND NUMBER OF RED AND WHITE CLOVER PLANTS SURVIVING ON THE DATE SHOWN

		Results at Seeding-rates indicated								
	Seeding-rates of Short Rotation Ryegrass	0 lb./ ac.	10 lb./ ac.	15 lb./ ac.	20 lb./ ac.	30 lb./ ac.	40 lb./ ac.	60 lb./ ac.	Results of F Tests	d.05 (where F Sig.)
	Viable seeds sown per sq. ft. (2.4.52)	19.1	19.1	19.1	19.1	19.1	19.1	19.1		
Red Clover	Number of Emerged Seedlings per sq. ft. (16.5.52)	14.3	13.25	12.4	12.1	14.75	14.8	13.7	(*)	2.20
Red Clover	Percentage Emergence of Viable Seeds Sown	74.9	69.4	64.9	63.4	77.2	77.5	71.7	(*)	11.52
Red Clover	Number of Plants Surviving per sq. ft. (16.9.52)	15.0	11.75	12.1	10.5	10.0	10.0	9.4	*	3.44
	Viable Seeds Sown per sq. ft. (2.4.52)	48.0	48.0	48.0	48.0	48.0	48.0	48.0		
White Clover	Number of Emerged Seedlings per sq. ft. (16.5.52)	34.8	35.1	32.4	30.6	35.1	34.3	35.3	*	3.07
White Clover	Percentage Emergence of Viable Seeds Sown	72.9	73.1	67.5	63.75	73.1	71.5	73.5	*	6.40
White Clover	Number of Plants Surviving per sq. ft. (16.9.52)	33.4	27.0	23.75	23.9	23.25	21.25	16.9	**	4.02

d.05 difference required for significance at the 5% level of probability
** differences significant at the 1% level of probability
* differences significant at the 5% level of probability
(*) differences almost significant at the 5% level of probability
Results of F tests on Survival Counts are from Analyses of Covariance (using Emergence Counts).

TABLE VIII. REGRESSION ANALYSES TO SHOW RELATIONSHIP OF NUMBER OF SURVIVING PLANTS OF RED AND WHITE CLOVER ON 16/9/52 AND RYEGRASS SEEDING RATE

Source of Variation	d.f.	F Reqd. 5% (1%)	Red Clover		White Clover	
			Mean Sq.	F	Mean Sq.	F
Linear Regression of Number of Surviving Plants on Seeding Rate	1	4.45 (8.40)	63.18	11.53**	488.94	71.20**
Increment due to Curvilinearity	1	4.45 (8.40)	20.50	3.74(*)	59.13	8.61**
Deviations from Curved Regression	4	2.96 (4.67)	9.29	1.70—	23.19	3.38*
Residual (from Analysis of Covariance)	17		5.48		6.87	

** significant at the 1% level of probability
* significant at the 5% level of probability
(*) almost significant at the 5% level of probability
— not significant

DISCUSSION

In this experiment, relationships of yield and development of sown species to seeding rate of short rotation ryegrass have been established. These relationships vary with the different species and change with successive seasons, but it is considered that they follow a logical sequence, determined by the interaction of light and soil nitrogen and growth of sown species.

The emergence of red and white clover plants, expressed as percentage emergence of viable seeds sown, was approximately 70 per cent for all treatments. During the following 18 weeks some plants died. The percentage survivals for red clover decreased regularly from 89 per cent at the lightest rate to 68 per cent at the heaviest rate, and for white clover, from 77 per cent to 48 per cent. Seedling survival, however, does not give a full picture over this period; total clover herbage production decreased proportionately to increase in ryegrass seeding rate and approximately three times as great a yield was obtained from Treatment 2 as from Treatment 7.

The number of ryegrass seedlings counted (shortly after emergence) was approximately 65 per cent of viable seed sown with no significant

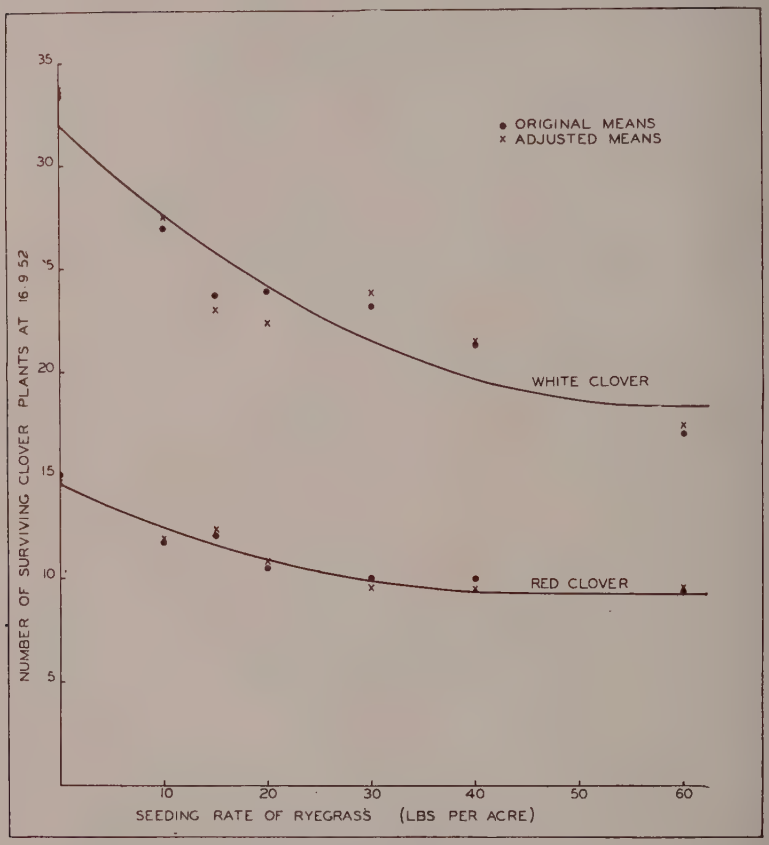

FIG. 7.—Relationship of Numbers of Surviving Clover Plants and Seeding Rate of Short Rotation Ryegrass together with the Experimental Data.

differences between treatments. The observation made by Williams (1947) that percentage emergence increased with reduction of seeding rate was, therefore, not confirmed (c.f. Parts II and III). The ratio of emerged seedlings per unit area at the lightest rate to the heaviest rate was approximately 1 : 6. When the surviving clover plants were counted 18 weeks after emergence, the ryegrass plants had already developed to a stage where it was impracticable to distinguish separate plants. Instead, the densities of ryegrass were determined by counting tillers, which even at this early stage in the development of the plant are virtually separate functional units within an association. At 18 weeks there was still a linear relationship between tiller numbers per unit area and ryegrass seeding rate, but comparing Treatments 2 and 7, the 1 : 6 ratio in tiller population observed at emergence had changed to one of about 5 : 8. This last ratio did not change substantially over the following 9 weeks.

A further measure of ryegrass vigour lies in the weight of individual tillers. At 18 weeks from emergence there were no significant differences between treatments; at 27 weeks, tiller weights showed a linear decrease with increasing seeding rate, the weight of tillers in the lightest rate being approximatly 50 per cent greater than those in the heaviest rate. Hence at this latter stage, the weight of tillers per unit area, determined by the product of numbers of tillers per unit area and mean weights, was virtually the same for all seeding rates.

The explanations advanced for the changing patterns and end results outlined above are based primarily on inter and intra-species competition for two components of the environment, light and nitrogen. There can be little doubt both from observations made during this experiment and from published information (Blackman, 1934, 1938; Sears, 1950; Donald, 1951) that the decrease in clover yield with increase in ryegrass seeding rate was due primarily to overshading of the clover seedlings by the more aggressive ryegrass. Insufficient light was available for adequate photosynthesis and this resulted in clover mortality and lack of seedling vigour. There was, however, an indirect result of far greater importance than a progressive decrease in the contribution of clover to the total yield. Nitrogen fixation by clovers, which is quantitatively much the most important source of soil nitrogen for pastures grown under the conditions of the present trial (Sears *et al.*, 1953d and e), is directly dependent on the photosynthetic activity of the clover leaves. It is obvious that in this important respect the treatments involving heavier ryegrass seeding rate were already at a marked disadvantage by the 18-week stage.

Competition for nitrogen expresses itself only in the ryegrass component, and although analyses were not made nor the effects of added nitrogen determined at any stage in the trial, the validity of the argument for regarding lack of nitrogen as a limiting factor in ryegrass growth, particularly during the second period at the higher seed rates, is consistent with the results obtained by other workers at this Division over the past fifteen years (Sears *et al.*, 1948; Melville and Sears, 1953; Sears, 1953b and c).

Up till the end of the second period, ryegrass so dominated the associations that the competitive effect of clover was almost negligible. Figure 5 shows that after 18 weeks from emergence the numbers of tillers per plant decreased with increase in seeding rate and that approximately three times as many tillers per plant were present at the lightest rate as at the heaviest rate. This relationship remained substantially the same during the next 9 weeks. In view of results obtained by Donald (1951) and Mitchell (1953), it appears most probable that the decrease in tiller numbers per plant was due to competition among tillers for light. Moreover, since Mitchell obtained his results at high soil nitrogen and mineral levels it would appear unnecessary to postulate that any other environmental factor was seriously limiting ryegrass development.

At 18 weeks from emergence, tiller weights showed no significant differences, but over the next 9 weeks mean tiller weight in the lighter seeding rates increased markedly. It was in this period that the nitrogen fixing capacities of clovers in the light seeding rate treatments

was much greater than in the heavier seeding rate treatments. Other trials have shown that during this peak-growing period growth of grasses is liable to be limited by available nitrogen (Corkill, 1949; Sears *et al.*, 1953*e*), and it is assumed, therefore, that where ryegrass was sown at the heavier rate, inter-species competition for light was followed by intra-species competition for nitrogen.

The results obtained from total herbage and species yields are readily explained in terms of this inter and intra-species competition for light and nitrogen. Over the winter, the dominant component of the pastures was ryegrass, and the responses to the treatments were largely determined by growth of this species. For ryegrass, increase in yield was proportional to rate of sowing, and this result is in keeping with the finding of Donald (1951). A comparison of the ratios of ryegrass yields obtained from Treatments 2 and 7 at the first and final grazings over the winter period, supports the view that competition for light and possibly also for nitrogen came into effect at an early stage. At the first grazing, the ratio was approximately 1 : 6, and at the final grazing it was approximately 5 : 6. Treatments 3–6 gave intermediate ratios. This suggests that competition among ryegrass plants occurred first in the heaviest sowings and last with the lightest sowings.

The effect of inter-species competition for light on clover growth, over the winter, is evident in the clover yields, which decreased proportionately to increases in ryegrass seeding rate. Table I indicates a similar relationship between ryegrass seeding rate and yields, obtained from unsown species, although the results were not analysed statistically.

The over-all result obtained in the winter period is shown by the relationship of total yield to ryegress seeding rate. This showed the same linear trend as ryegrass yields. Because of greater yields of clover and less weed suppression at the lower rates, however, the rate of increase in total yield per 1 lb. increase in seeding rate is less than the rate of increase for ryegrass yield.

During the spring (25–41 weeks from sowing), competition between ryegrass plants and between tillers for available soil nitrogen became evident, and it expressed itself in an identical manner to inter-species competition for light during the first period. Shortage of nitrogen for ryegrass growth was manifested first at the higher seeding rates, and towards the end of the spring at the intermediate rates. At the lighter seeding rates, however, clover established successfully, with consequent improvement in soil nitrogen supply. This was reflected in increased vigour of the ryegrass plants and their component tillers.

At the heavier seeding rates, the relatively poor growth of ryegrass during the spring reduced competition for light, and resulted in rapid development of surviving clover plants. The increase in the proportion of clover to total yield was also probably increased by the germination of buried hard clover seeds (Hyde and Suckling, 1953). A period of relatively good clover growth followed, coupled with a nitrogen build-up, and consequently at a later stage during the spring good growth of ryegrass was obtained. Towards the end of spring this

effect was noticeable, but to a lesser degree, at the intermediate rates. The net result during the spring was a linear decline of total yield with increasing ryegrass seeding rate.

During the summer and early autumn the yield of ryegrass was little more than that of clovers and did not vary with seeding rate. Clover yields, however, were highest at the intermediate seeding rates and were determined, to a large extent, by the proportion of clovers at the commencement of summer. At this stage, the proportion of clovers was greatest at the intermediate seeding rates and consequently highest yields of clover, particularly red cover, were obtained at these rates. However, the grazing height was not conducive to the production of maximum yields of red clover and differences were therefore not large.

Over the total period, ryegrass yields showed a steady increase with seeding rate, but tended to level out at higher rates. Clover yields declined steadily with increasing ryegrass seeding rates and unsown species showed the same trend. Despite the marked changes in yields and grass-clover ratios from season to season, total yields for the full period showed no significant differences.

A comparison of the yields of Treatments 1 and 2 indicates that ryegrass competed with clovers and unsown species to a considerable degree even at the lightest seeding rates, although the intensity of competition did not appear sufficient to cause limitation of ryegrass growth through nitrogen deficiency.

Acknowledgement

For statistical interpretation of the experimental data, particular acknowledgement is made to Mr. A. C. Glenday, Applied Mathematics Laboratory, Department of Scientific and Industrial Research.

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PASTURE ESTABLISHMENT STUDIES

II. THE INFLUENCE OF HERBAGE HEIGHT AT GRAZING, AND OF GRASS SEEDING RATE, ON THE ESTABLISHMENT AND DEVELOPMENT OF PASTURES OF SHORT ROTATION RYEGRASS, RED AND WHITE CLOVERS

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(Received for publication, 23 February 1954)

Summary

Pastures were sown in the autumn with red and white clovers and with short rotation ryegrass, at rates of 15 lb. and 40 lb. per acre respectively.

The plots were grazed when the herbage had grown to a specified height. Initially two treatments were applied: grazings at 3 in. and 9 in. On some of the pastures, these grazing treatments were applied throughout the experiment, while in others they were reversed during the course of the experiment.

The effects of ryegrass seeding rate on the establishment and development of sown species were similar to those reported in Part I.

Grazing at 9 in. resulted in greater total yield than grazings at 3 in.

Where ryegrass was sown at the lower rate, the 9-in. grazing treatment did not affect clover seedlings adversely, but at the higher seeding rate this grazing treatment resulted in clover suppression during the winter and unthrifty ryegrass growth in the spring. Grazing the herbage at 3 in. resulted in good clover establishment at both seeding rates.

It is concluded that sowing short rotation ryegrass at the lower seeding rate is advantageous because increased latitude in frequency of grazing is obtained, without adverse effects to clover establishment.

Introduction

In the experiment reported in Part I of this series, it was found that sowing ryegrass seed at high rates per acre resulted in a dense growth of grass herbage in the winter with consequent suppression of clover seedlings. In the following spring, ryegrass growth was unthrifty because of inadequate nitrogen fixation. Where ryegrass was sown at lighter rates, grass yields were lower in the winter, but clovers established well, and spring yields of ryegrass were higher. In that experiment the first three grazings occurred whenever the herbage reached a height of 3–4 in. Subsequent grazings took place when the herbage height was about 6 in. Work by Sears (1950) suggested that had the pastures been grazed at a different height other patterns of development might have been produced.

Sears investigated the establishment of pastures, developing from autumn sown mixtures of both perennial ryegrass (*Lolium perenne*) and short rotation ryegrass (*L. perenne x L. multiflorum*) sown at 40 lb. per acre, with red clover (*Trifolium pratense*) and white clover (*T. repens*) and showed that herbage height at grazing markedly influenced the pattern of development. When these pastures were grazed at a herbage height of 9–12 in., severe clover suppression occurred in the early stages, due to initial high yields of ryegrass,

This resulted in decreased yields of ryegrass at later stages, through nitrogen deficiency. At a grazing height of 3–4 in., initial yields were lower, but the clovers established more successfully. Subsequent yields were therefore better than those of the 9–12 in. treatments. The effect of height of grazing on initial yields was in agreement with the general conclusion from studies on the effects of frequency of defoliation and height of cutting on pasture species (Stapledon, 1924; Stapledon and Milton, 1930; Graber, 1931; Richardson *et al.*, 1932; Jacques and Edmond, 1952). Sears aimed at the development of a well balanced pasture, and he found that the production of maximum initial yields was not compatible with successful establishment of sown species.

In view of the above, it was considered important to determine the interaction between seeding rate of short rotation ryegrass and herbage height at grazing, in the development of autumn sown pasture mixtures of short rotation ryegrass, and red and white clover. An experiment was therefore designed to determine the influence of herbage height at grazing on total growth and botanical composition of pastures, establishing from mixtures in which the ryegrass seeding rate varied.

Experimental Design and Procedure

The experimental area was at Palmerston North and was of recent silt, having been levelled by bulldozing from an old river bed course three years before the present experiment was laid down. When ploughed late in March 1952, the land had been in spaced plants of *Lotus* spp. for 3 years. During the preparation of the seed-bed, superphosphate was applied at 3 cwt. per acre. It is considered that the soil was of lower fertility than that used for the experiment reported in Part I of this series.

Two seeds mixtures were sown. In one there was 15 lb. of short rotation ryegrass per acre, 4 lb. of broad red clover and 3 lb. of white clover. The other comprised 40 lb. of short rotation ryegrass, 4 lb. of broad red clover and 3 lb. of white clover. All seed was of certified pedigree class and the sowing rates were on the basis of pure viable seed.

The plots were sown on 2 April 1952. To obtain an even spread, the seed was mixed with sawdust in the proportion of approximately 9 parts of sawdust to 1 part of seed. The plots were then tyne harrowed to obtain seed coverage.

The following grazing treatments were applied from sowing:

(1) Grazings at the 3–4-in. herbage height throughout the experiment (3 – 3).

(2) Grazings at the 9-in. herbage height throughout the experiment (9 – 9).

(3) Grazings at the 3–4-in. herbage height until the end of September 1952, followed by grazings at the 9-in. herbage height until the end of December 1952 (3 – 9).

(4) Grazings at the 9-in. herbage height until the end of September 1952, followed by grazings at the 3–4-in. herbage height, until the end of December 1952 (9 – 3).

The experiment was laid down as a 2 x 2 x 2 factorial design with three replications. Thus there were 12 plots of each seeding rate and 6 plots of each seeding-rate x grazing-treatment combination. The 24 plots, each 1 chain x ½ chain, were fenced so that each could be grazed separately. Mature wethers were used and replicate plots were grazed at the same time to avoid block to block transfer of fertility. Stock numbers were adjusted to ensure that the grazing periods for all plots were approximately the same. The criteria used for deciding when a plot should be grazed was average herbage height. The term grazing height refers throughout to the height of herbage at the commencement of grazing.

At each grazing two 10 ft. x 4 ft. frame enclosures were placed at random within each plot. Towards the end of each grazing period the enclosed herbage was cut by hand-shears down to the height of the surrounding grazed pasture, and after weighing, a sample of the cut herbage was taken for dry matter determinations and botanical analyses. The remainder was returned to the plots and eaten by the sheep (Sears, 1951). Botanical analyses of individual plots were obtained at only a few of the grazings. For the majority of grazings a composite sample of replicate plots was analysed, so that a botanical analysis for each treatment at each grazing was obtained.

Emergence counts of each species and one subsequent clover population count were made. The percentage emergence for each species was calculated from the seedling counts and the estimated number of viable seeds sown. A quadrat 3 ft. long by 4 in. wide was used for these counts and random samples sufficient in number to give statistical accuracy were obtained at each count, by sampling and analysing sequentially.

Because of flooding in January, 1953, the experiment was concluded on 31st December 1952. The results obtained by that date gave sufficient conclusive information to justify publication.

Results

Total Herbage Production and Species Yields

Only the total herbage yields were analysed statistically. Statistical analyses of the yields of separate species could not be made because botanical analyses of separate plots were not obtained at all grazings. Conclusions drawn from species yield data, in what follows then, have been deduced with reference to total yield differences and botanical analyses. It is considered that where such deductions have been made these are valid and are a true picture of what occurred.

The yields, which are expressed throughout as lb. dry matter per acre, are presented separately for two periods. The first period extended from 2 April 1952 to 1 October 1952, when only two grazing treatments were compared, and the second from 1 October 1952 to 31 December 1952, during which time the reversal treatments were applied.

First Period (2/4/52–1/10/52)

Table I gives total and species yields of the two pastures grazed at 3 in. and 9 in. respectively.

TABLE I. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR THE PERIOD 2/4/52–1/10/52

Rate of Ryegrass Sowing (lb./ac.)	Grazing Height (in.)	No. of Grazings	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
				Ryegrass	Clover			Unsown Species
					Red	White	Total	
15	3	4	3030	2660	60	95	155	215
	9	2	4150	3650	110	120	230	270
40	3	5	2970	2790	35	45	80	100
	9	2	4030	3900	60	25	85	55

The S.E.s of the Total D.M. Yields are ± 207.7 and the corresponding detectable differences at the 5% (1%) levels are 617.2 (845.4).

ANALYSIS OF VARIANCE FOR TOTAL DRY MATTER YIELDS SHOWN IN TABLE I

Source of Variation	d.f.	Mean Sq.	F	F Reqd. 5% (1%)	Result
Blocks	2				
Seeding Rate	1	51,801	0.20	4.41 (8.28)	—
Grazing Height	1	7,144,959	27.60	4.41 (8.28)	**
Rate x Height	1	7,957	0.03	4.41 (8.28)	—
Residual	18	258,874			

Coefficient of Variation = 14.4%

** significant at the 1% level of probability.

— differences not significant

TABLE II. SEEDING RATE AND GRAZING HEIGHT MEANS FROM TABLE I

Means	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
		Ryegrass	Clover			Unsown Species
			Red	White	Total	
Low Seeding Rate	3590	3150	90	110	200	240
High Seeding Rate	3500	3340	40	40	80	80
3-in. Grazing Height	3000	2720	50	70	120	160
9-in. Grazing Height	4090	3770	80	70	150	170

The S.E.s of the Total D.M. Yields above are ± 146.9, and the detectable differences at the 5% (1%) levels are 436.4 (597.8).

The following deductions are drawn from Tables I and II:

Seeding Rate: Total yields did not differ significantly. Ryegrass yields were also approximately equal for the two rates, but there were increases in yields (although small in comparison with total growth) of clover and unsown species at the lighter seeding rate. This is also shown in Table II.

Grazing Height: Total yields obtained from the 9-in. grazing treatments were significantly greater (1% level) than those from the 3-in. treatments. The increase was approximately 30 per cent. A similar difference is shown for ryegrass yields. Yields of clovers and unsown species were approximately the same.

Seeding Rate x Grazing Height Interaction: There was no evidence of an interaction between seeding rate and grazing height. That is, the increase in total yield due to herbage height at grazing was not modified by ryegrass seeding rate. For clover yields, however, there was some evidence of such an interaction. Table I shows an approximate 50 per cent increase in clover yield at 9 in. for the low seeding rate, whereas, for the high seeding rate, yields obtained from both grazing heights were about equal.

Second Period (1/10/52–31/12/52)

Table III gives the total and species yields from the start of the reversal treatments to the end of the experiment.

Deductions from Tables III and IV are:

Seeding Rate: The total yield obtained from the light ryegrass seedings was significantly greater (1 per cent level) than that from the heavy seedings. The difference was approximately 20 per cent, and Table IV shows that it was due to a greater yield of ryegrass from the lighter seedings. Total clover yields were approximately equal. Table III, however, shows considerable differences in clover yieds due to seeding rate, particularly in the (9 – 9) grazing treatments. An approximate 75 per cent increase was obtained in favour of the lighter rate at the (9 – 9) grazing height. For the (3 – 3) and (9 – 3) comparisons, the differences were approximately 20 and 25 per cent respectively, in favour of the lighter rate, and for the (3 – 9) comparison, a similar difference was obtained, but in favour of the heavier rate. These clover yield differences due to seeding rate, are not apparent when rate means are combined, as in Table IV.

Grazing Height:

The total yield obtained from the 9-in. grazing treatment was significantly greater (5 per cent level) than that from the 3-in. treatments. As shown by Table IV the increase was due to an increase in clover growth and was obtained mainly from the (3 – 9) treatment. Ryegrass yields for both grazing heights were approximately the same.

Influence of First Period Grazing Treatments on Second Period Yields: Although a highly significant increase in total yield was obtained from the 9-in. grazings in the first period (Table II), Table IV

TABLE III. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR THE PERIOD 2/10/52–31/12/52

Seeding Rate (lb./ac.)	Grazing Height (in.)	No. of Grazings	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
				Ryegrass	Clover			Unsown Species
					Red	White	Total	
15	3—3	4	5780	5010	375	270	645	125
	9—9	3	5900	5030	545	290	835	35
	3—9	3	6510	5010	785	650	1435	65
	9—3	5	6150	5590	190	230	420	140
40	3—3	4	5000	4360	180	360	540	100
	9—9	3	5210	4700	320	160	480	30
	3—9	3	5780	4030	800	920	1720	30
	9—3	5	4520	4130	200	130	330	60

The S.E.s of the Total Dry Matter yields above are ± 283.5, and the detectable differences at the 5% (1%) levels are 873.6 (1224.8).

ANALYSIS OF VARIANCE (TOTAL D.M. YIELDS)

Source of Variation	d.f.	Mean Sq.	F	F Reqd. 5% (1%)	Result
Blocks	2				
Seeding Rate	1	6,411,834	26.59	4.75 (9.33)	**
Height of Grazing (2nd Period)	1	1,767,465	7.33	4.75 (9.33)	*
Height of Grazing (1st Period)	1	859,195	3.56	4.75 (9.33)	(*)
Rate x Height (1st Period)	1	442,545	1.84	4.75 (9.33)	—
Rate x Height (2nd Period)	1	606,426	2.51	4.75 (9.33)	—
Height (1st Period) x Height (2nd Period)	1	270,725	1.12	4.75 (9.33)	—
Rate x Height (1st Period) x Height (2nd Period)	1	518,910	2.15	4.75 (9.33)	—
Residual	12	241,133			
Total	21				

Coefficient of Variation = 8.8%
** significant at the 1% level of probability
* significant at the 5% level of probability
(*) significant at the 10% level of probability
— difference not significant

(In this analysis, two missing items were estimated by minimizing the Residual Sum of Squares).

TABLE IV. SEEDING RATE AND GRAZING HEIGHT MEANS FROM TABLE III

		Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
			Ryegrass	Clover			Unsown Species
				Red	White	Total	
Seeding Rate	15 lb./ac.	6090	5160	480	360	840	90
	40 lb./ac.	5130	4310	380	390	770	50
2nd Period Grazing Height (in.)	3	5360	4770	240	240	480	110
	9	5850	4690	610	510	1120	40
1st Period Grazing Height (in.)	3	5770	4600	540	550	1090	80
	9	5440	4860	310	200	510	70

The S.E.s of the Total Dry Matter yields above are ± 141.8, and the detectable differences at the 5% (1%) levels are 437 (612).

shows that there was a significant decrease (10 per cent level) in the second period due to the 9-in. grazing treatments in the first period. The decrease was due in part to reduced clover yields and was influenced by the grouping of treatment combinations. The (3 – 9) treatments with large clover yields, for instance, are included in the 3-in. grazing height mean. The relatively low total yield of the (9 – 3) treatment at the lighter seeding rate also contributed to the decrease in total yield.

Interactions: None of the interactions reached significance level.

The experiment was terminated abruptly by the flooding of the land in January 1953. The replicates of two treatments only were unaffected by the flood and measurements were continued on these for a further 47 days.

The results presented in Table V show that where the herbage was grazed at 9 in. throughout the experiment, much better growth of clover was obtained from the lighter sowings of ryegrass. Yields of ryegrass were approximately equal for both sowing rates.

TABLE V. TOTAL AND SPECIES YIELDS (lb. D.M./ac.) FOR THE (9 – 9) TREATMENTS AT BOTH SEEDING RATES OBTAINED ON 16/2/53 (47 days of growth)

Seeding Rate (lb./ac.)	Grazing Height (in.)	Total Yield (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)				
			Ryegrass	Clover			Unsown Species
				Red	White	Total	
15	(9—9)	2830	2090	550	180	730	10
40	(9—9)	2080	1970	60	40	100	10

Plant Population Counts: Percentage emergence of ryegrass seedlings did not differ significantly. At the low seeding rate 72.1 per cent of viable ryegrass seeds emerged and at the high rate 73.8 per cent.

For clover, 66.8 per cent of red and 65.6 per cent of white clover seeds emerged over all treatments. No significant differences in percentage emergence were obtained.

The results presented in Table VI show numbers of red and white plants per square foot surviving under the various treatments at 22/8/52. Analyses of Covariance were performed to adjust the data for variation in emergence counts.

TABLE VI. NUMBER OF CLOVER PLANTS SURVIVING UNDER VARIOUS TREATMENTS

Seeding Rate (lb./ac.)	Grazing Height (in.)	Red Clover	White Clover	Total Clover	Adjusted Total Clover
15	3	9.9	20.3	30.2	30.9
	9	9.2	19.3	28.5	26.9
40	3	8.0	20.2	28.2	28.3
	9	7.5	13.0	20.5	21.3

The clover means shown in the last column have been adjusted by the use of initial emergence counts.

The Standard Error of these means is ± 1.79 and the differences between them required for significance at the 5% (1%) levels are 5.4 (7.4).

ANALYSIS OF COVARIANCE
(Total Clover Survivals on Emergence Counts)

Source of Variation	d.f.	Mean Sq.	F obtained	F Reqd. 5% (1%) pt	Result
Rate (adjusted)	1	183.29	4.79	4.45 (8.40)	*
Height (adjusted)	1	331.20	8.65	4.45 (8.40)	**
Rate x Height (adjusted)	1	19.79		4.45 (8.40)	—
Error	17	38.30			

Coefficient of Variation = 23.0%
** significant at the 1% level of probability
* significant at the 5% level of probability
— no significant difference

Deductions from Table VI are:

Seeding Rate: The mean count of clover seedlings per square foot for the light seeding rate was significantly higher (5 per cent level) than the mean for the heavy seeding rate. The 15 lb. per acre mean was 28.9 plants per square foot, and the 40 lb. per acre mean, 24.8 plants per square foot.

Height of Grazing: The mean count for the 3-in. grazing treatments was 29.6 plants per square foot, and for the 9-in. grazing treatments, 24.1 plants per square foot. The difference was significant (1 per cent level).

Seeding Rate x Grazing Height Interaction: There was no significant interaction, i.e., the difference due to height of grazing was not modified by seeding rate.

Individual Treatments: (i) The mean count for the 40 lb. per acre seedings grazed at 9 in. was significantly lower than any other combination. (ii) The mean counts for the 15 lb. per acre seedings grazed at 9 in. and the 40 lb. per acre seedings grazed at 3 in. did not differ significantly.

Discussion

In the first paper of this series it was demonstrated that the production of high early yields of herbage from ryegrass-clover pastures sown at high seeding rates, resulted in reduced yields at later stages. The initial high yields were obtained almost entirely from ryegrass and were associated with severe clover suppression and hence with poor nitrogen fixation.

Insofar as the ryegrass seeding rates in the present experiment were the same as two out of the seven treatments in Part I, a comparison can be made between the herbage yields obtained in the two experiments. In the present experiment, as shown in Tables I and II, yields obtained for the first six months from both rates of sowing did not differ significantly. Although not shown separately, yields obtained over the first three months, from the 40 lb. seeding rate, were approximately 20 per cent greater than those from the 15 lb. rate. During the following three months the position was reversed, and the light seeding rate treatment continued to produce heavier yields up to the end of the experiment. In the previous trial the difference in favour of the 40-lb. seeding rate was approximately 25 per cent over the first six months, with no significant difference in yield for the following three months. It is considered that the smaller difference in yields in the present trial and the earlier reversal of trends was due to lower initial soil fertility. The effect was most marked in ryegrass yields and this is in accordance with observations made by Sears (1953).

The present paper also extends the conclusions reached in Part I, by introducing the further variable of grazing height. For both periods, the results agree with the general conclusions of many workers (Hudson *et al.* 1933; Sears 1949; Wagner 1952) that increased heights of grazing, or increased intervals between grazings, result in increased yields of herbage. In the first period, the increased yield amounting to approximately 35 per cent, was due to additional ryegrass growth, whereas in the second period the increase was due to additional clover growth. Ryegrass yields for this period were approximately the same.

Different patterns of development due to grazing height were obtained, however, at the two seeding rates. Where ryegrass was sown at 40 lb. per acre and the pastures grazed at 9 in. throughout,

the high initial ryegrass yields obtained were associated with clover suppression. For the (3 – 3) treatments at this seeding rate, lower initial ryegrass yields were obtained, but as shown in Table VI and from observations, clover survival and development were much better.

Where ryegrass was sown at 15 lb. per acre, early ryegrass yields were lower under both grazing treatments, but they rapidly increased so that 6 months after sowing the aggregate yields were equal to those obtained at the higher seeding rate. Clover seedlings developed faster and more of them survived. This effect of ryegrass seeding rate on clover development was most marked under the 9-in. grazing treatments, and is well illustrated by the results obtained 47 days after the enforced ending of part of the experiment, and presented in Table V.

The results (like those reported in Part I) can be explained on the basis of inter-species competition for light in the early stages of development. The higher the rate at which the ryegrass is sown, the earlier are the clover seedlings restricted in their growth by shading, and the effect is intensified when the herbage in the pasture is not grazed off at a relatively low height, and also when the fertility of the soil is high.

The results presented in Table II show that pastures developing from light seedings of short rotation ryegrass can also withstand the relatively harsh management of the (9 – 3) treatment better than the heavier seedings. A significant decrease in total yield is shown for the (9 – 3) treatment compared to the (9– 9) at the high seeding rate, whereas the same comparison, at the low rate, does not show this significant decrease. If ryegrass yields are compared, there is, in fact, a complete reversal in differences. An approximate difference of 15 per cent is shown in favour of the (9 –9) treatment at the heavy rate, and at a similar difference, but in favour of the (9 – 3) treatment, is shown at the light rate. The explanation offered is that, because of better top and root growth of individual plants (particularly ryegrass) in the pastures developing from the lighter seedings, a larger supply of stored plant nutrients is available for regrowth following grazings. These plants can then withstand better the harsher management of 3 in. grazings following 9 in. grazings, than the less well developed plants in the heavier sowings.

The grazing height applied in the first period strongly influenced the yields, especially the clover yields, in the second period. This is apparent from a comparison of the yields of all plots under the (3 – 9) and the (9 – 9) grazing treatments. During the first period, the competitive effect of ryegrass on clover plant development was less for the 3-in. grazing treatment. At the changeover the potential for clover growth was therefore better in these pastures, and consequently, when the grazing treatment was changed to 9 in., more vigorous growth of clover followed in these treatments than in the (9 – 9) treatments.

It is concluded that low seeding rates of short rotation ryegrass result in better development of individual plants of all species in the pasture. Because of this, greater latitude in grazing height can be tolerated during the establishment of the pasture and this is of con-

siderable importance in farming practice. Bad weather conditions, especially where there is the risk of pugging, can prevent the stocking of new pastures at a particular height of growth, and when the necessity for frequent grazings is removed, increased herbage yields can be obtained without adverse effects to the developing pastures.

ACKNOWLEDGEMENT

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DURATION OF EFFECTIVENESS OF SOME ORGANIC PHOSPHORUS INSECTICIDES AGAINST *Myzus persicae* (Sulz.) ON SWEDES

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(Received for publication, 15 February 1954)

Summary

Application of parathion to the foliage reduced aphid population to a minimum within two days after treatment. Parathion was no longer effective subsequent to four days after spraying. Aphid numbers on plants sprayed with Isopestox and schradan reached a minimum at four days after spray application, and then increased on plants treated with Isopestox, whilst schradan proved effective for ten days. Interaction of plant age and effectiveness of treatments were not significant.

Application to the soil of schradan compounds reduced the population of *Myzus persicae* (Sulz.) on swedes to a minimum in eight days and kept aphid numbers at a low level for a period of 75 days after treatment. Isopestox and parathions acted more rapidly than schradan but ceased to be effective eight days after treatment.

Introduction

Some organic phosphorus compounds are capable of being absorbed through both leaves and roots and translocated in the sap stream of the plant, rendering it toxic to sucking insects. Experiments reported here were carried out to investigate the residual effects of some of these compounds on the aphid *Myzus persicae* (Sulz.) on swedes *Brassica napobrassica* DC.

Materials

The following chemicals were used:—

Isopestox (90 per cent bis dimethyl amino fluorophosphine oxide), a water miscible preparation;

Pestox 3 (66 per cent schradan and related compounds), a water miscible preparation;

Sytam (70 per cent schradan), a water miscible preparation;

Murphos 20 (20 per cent parathion), an emulsifiable preparation;

Thiophos (15 per cent parathion), a wettable powder.

Experimental Methods and Results

Foliage application

Swede plants grown in potting soil in six-inch pots were arranged into four different age groups. At the time of treatment these plants were 4, 6, 8 and 10 weeks old respectively. Solutions containing 0.1 per cent of Isopestox, Sytam and Thiophos were applied to four plants of each age group, i.e. 16 plants per treatment. The surface of the soil was covered to prevent contamination, and 56 ml. of spray were applied to each plant. The same volume of water was applied to check plants. Pots were arranged in randomized blocks on glasshouse benches and each plant covered with a muslin cage supported by a wire frame. Twenty-four hours after treatment, 10 nymphal, apterous *Myzus*

persicae were placed on each plant. Counts were made at intervals of 1 to 3 days. When live aphids were no longer found on a replicate, a further 10 nymphal aphids were placed on that plant.

Results of aphid counts after foliage treatment are summarized in Fig. 1.

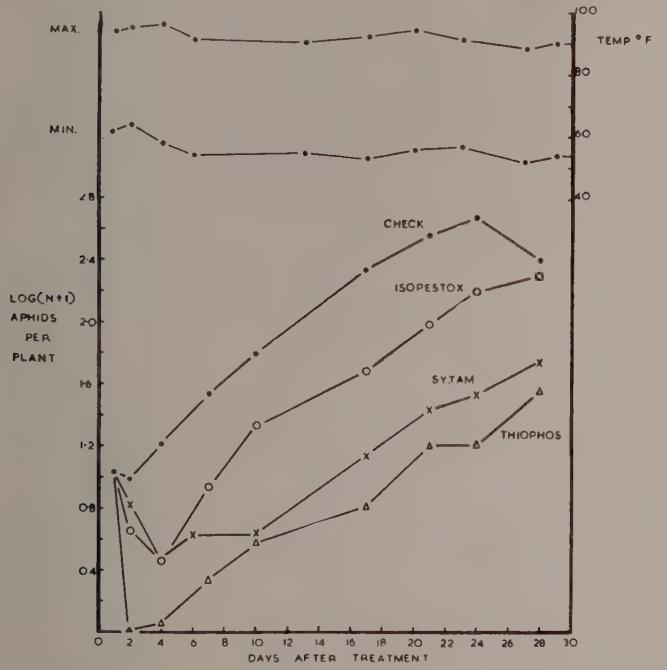

FIG. 1.—Effect of foliage application of Isopestox, Sytam and Thiophos on aphid population on swedes. Differences for significance on selected days:

Day	5%	1%
4	0.17	0.23
10	0.23	0.30
21	0.29	0.39

The transformed aphid counts on days 4, 10 and 21 after treatment were subjected to statistical analysis, and differences for significance at 5 and 1 per cent levels are given in the caption of Fig. 1. No significant differences were found between plant age groups, so these are combined in Fig. 1. Each point in the graph therefore represents the mean obtained from 16 plants.

Thiophos reduced the aphid population to a minimum two days after treatment, but from the fourth day after treatment the aphid population increased at a comparable rate to that of checks. Sytam and Isopestox were slower in taking effect, aphid numbers reaching a minimum on the fourth day after treatment. From then onward the rate of increase of aphids on plants treated with Isopestox was similar

to that on checks. Sytam, however, reduced aphid numbers until the tenth day after treatment, but reproduction rate after the tenth day was normal.

Fresh and dry weights of plants were determined at the conclusion of this test and there were no significant differences between age groups and treatments.

Soil Application

Soil application

Three-weeks-old swede plants, grown in a manner similar to plants used previously, were used in this trial. Each pot was treated with 100 ml. of a 0.1 per cent solution of Isopestox, Murphos 20, Thiophos, Sytam or Pestox 3. Insecticides were applied evenly to the soil surface. Checks received 100 ml. water per pot. Each treatment was replicated six times. For the remainder of the experiment the method followed the description given previously. The mean aphid counts per plant are summarized in Figs. 2 and 3.

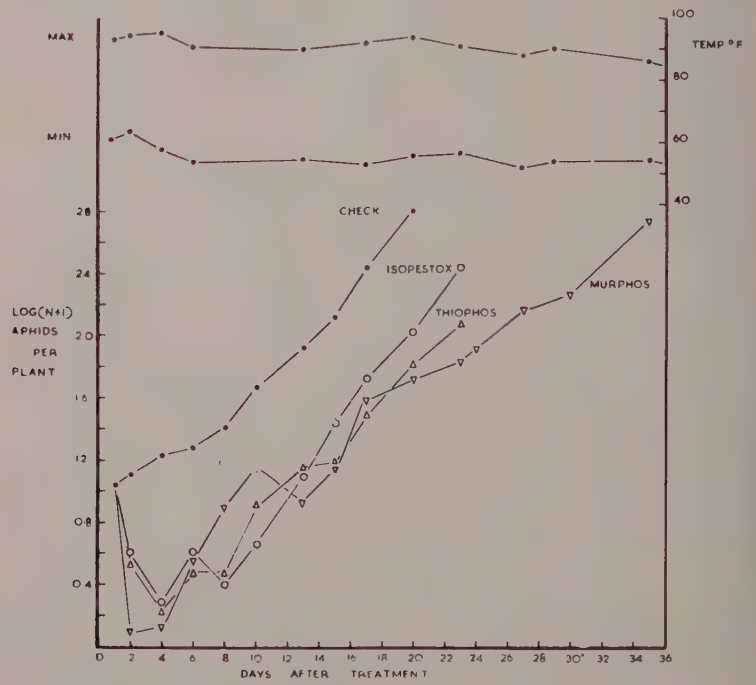

Fig. 2.—Effect of soil applications of Isopestox, Murphos 20, and Thiophos on aphid population on swedes. Differences for significance on selected days:

Day	5%	1%
4	0.31	0.42
8	0.38	0.51
20	0.46	0.63

On plants grown in soil treated with Isopestox, Murphos 20 and Thiophos (Fig. 2), aphid numbers decreased rapidly, reaching a mini-

mum within four days after treatment. Murphos 20 had a greater immediate effectiveness than Isopestox and Thiophos. After the fourth day the aphid populations increased steadily on plants treated with Isopestox, Murphos 20 and Thiophos and at rates comparable with that on checks. Between the sixth and eighth day, Isopestox, and between the tenth and fourteenth day, Murphos 20, showed decreases in aphid populations, but these variations had little effect on the general upward trend.

On plants grown in soil treated with Pestox 3 and Sytam (Fig. 3), the aphid populations decreased less rapidly than on Isopestox and parathion (Murphos 20 and Thiophos) treatments. After reaching a minimum on the eighth day after treatment the aphid population on plants treated with schradan (Pestox 3 and Sytam) increased gradually at a rate significantly lower than that on checks. An increase in aphid numbers, comparable to an increase on checks, did not begin to develop until approximately 75 days after treatment. Differences between the effect of Pestox 3 and Sytam were not significant, but both were significantly better than check.

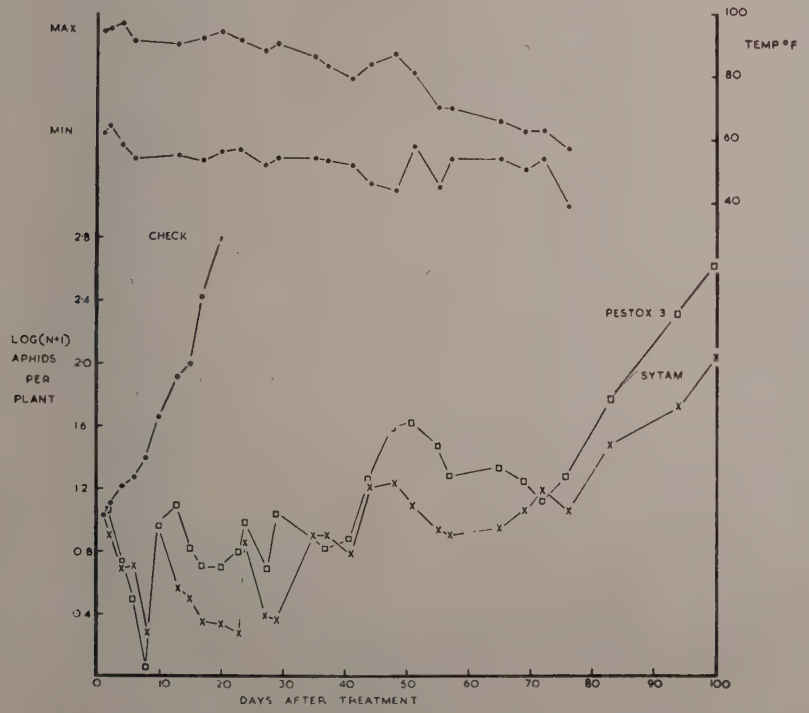

FIG. 3.—Effect of soil applications of Sytam and Pestox 3 on aphid population on swedes. Differences for significance on selected days:

Day	5%	1%
4	0.31	0.42
8	0.38	0.51
20	0.46	0.63

Aphid counts (transformed to log (n + 1)) on the 4th, 8th and 20th day after treatments were analysed, and differences for significance are given in the captions of Figs. 2 and 3.

Conclusions

Parathion gave significantly higher kill of aphids than schradan or Isopestox within four days after treatment. After the fourth day an increase in aphid population was observed in all treatments.

In soil applications parathion compounds and Isopestox were no longer effective after four days. Schradan compounds, however, remained effective for 75 days.

The residual action of schradan suggests the necessity for tests of specific insect and host plant combinations to assess the effect of this compound on edible crops, especially vegetables.

Acknowledgments

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PLANT QUARANTINE

III. LIST OF PLANT DISEASES AND PESTS INTERCEPTED IN NEW ZEALAND IN 1953

By H. Jacks, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(Received for publication, 1 March 1954)

Introduction

In this list are recorded plant diseases and pests intercepted in 1953 on plants and plant products introduced into New Zealand. Specimens were submitted by Horticultural Inspectors of the Department of Agriculture and identified by specialist officers of the Plant Diseases Division. Specimens submitted but found to carry organisms which could not be identified for various reasons, e.g., because of damage, failure in culture or rearing tests, etc., are not listed. Diseases and pests not established in New Zealand are marked with an asterisk.

LIST OF PLANT DISEASES AND PESTS INTERCEPTED IN NEW ZEALAND IN 1953

Disease or Pest		No. of Consignments	Host		Country of Origin	Discovered in:
Common Name	Generic Name		Common Name	Generic Name		
Diseases:						
Dry rot	*Fusarium* spp.	1	Potato	*Solanum tuberosum* L.	Scotland	Timaru
Grey mould	*Botrytis cinerea* Pers.	1	Rose	*Rosa* spp.	England	Wellington
Leaf spot	*Elsinoe venezuelensis* Bitancourt*	1	Croton leaves	*Codiacum variegatum* Blume	Norfolk Is.	Auckland
Powdery mildew	*Erysiphe cichoraccarum* D.C.	1	Perennial aster	*Aster* sp. cult.	England	Palmerston N.
Root rot	*Fusarium* spp.	1	Carnation	*Dianthus caryophyllus* L.	"	Timaru
Skin spot	*Oospora pustulans* Owen and Wakef.	1	Potato	*Solanum tuberosum* L.	Scotland	"
Virus	Cymbidium mosaic	1	Orchids	*Orchidaceae* (?)	Australia	Christchurch
Pests:						
Ants	*Paratrechina longicornis* Lat.	1	Vehicles	—	Pacific Is.	Rotorua
Aphids	*Cavariella aegopodii* Scop.	1	Celery	*Apium graveolens* L.	Australia	Palmerston N.
Banana spider	*Heteropoda vanatoria*	1	Banana	*Musa paradisiaca* L. var. *sapientum* Kuntze	Fiji	Christchurch
Black parlatoria scale	*Parlatoria zizyphus* Lucas*	1	Dried vegetable Produce	—	China	Palmerston N.

Beetles	*Dermestes maculatus* Deg.	1	Potato	*Solanum tuberosum* L.	Japan	New Plymouth
„	*Anobium* sp.	1	Kentia seeds	*Kentia forstiana* F. Muell.	Lord Howe Is.	Christchurch
Citrus red scale	*Aonidiella aurantii* Mask.	2	Orange, sweet	*Citrus sinensis* Osb.	Australia	„
Coffee Weevil	*Arecacerus fasciculatus* De G.	1	Nutmeg	*Myristica fragrans* Houtt.	Malaya	Dunedin
Diptera	Fam. *Chironomidae*	1	Vehicles	—	Pacific Is.	Rotorua
Fruit fly	*Drosophila bryani* Mall.	1	Aircraft	—	Fiji	Auckland
„ „	*Chaetodacus tryoni* Frogg.	1	„	—	Australia	Christchurch
Hymenopteron	*Paracolletes hirtipes* Smith	1	Vehicles	—	Fiji	Dunedin
Ichneumon	*Hymenoptera* gen. *Diadromus**	1	Aircraft	—	Australia	Christchurch
Lac insect	*Laccifer lacca* Kem.	1	Herbs	—	Malaya	Palmerston N.
Mirid bugs	*Sixconotus* sp. and *Halticatoma* sp.	1	Cactus	*Cactaceae* (?)	Mexico	Timaru
Mites	*Tyroglyphidae*	1	Kentia seeds	*Kentia forstiana* F. Muell.	Lord Howe Is.	Christchurch
„	*Bracobia practiosa* Koch.	1	Aircraft	—	Australia	„
Moth	*Tortricidae*	1	Coconut	*Cocos nucifera* L.	W. Samoa	Invercargill
Red Wax scale	*Cercoplastes rubens* Mask.*	1	Pointsettia	*Euphorbia pulcherrima* Willd.	Norfolk Is.	Auckland
Red Wax scale	„ „ „ *	1	Maple	*Acer* sp.	Australia	„
Snails	*Opeas* sp.	1	Croton leaves	*Codiaeum*, Juss. (?)	Fiji	„
Spider beetle	*Ptinidae*	1	Flower seeds	—	England	Christchurch
Stratiomyid	*Odontomyia parallelina* Bezzi*	1	Aircraft	—	Fiji	Auckland
Weevils	*Euscepes postfaciatus* Fairm.	1	Kumara	*Ipomoea* spp.	Pitcairn Is.	„
„	*Rhyctinus callosus* Boh.	1	Banana	*Musa paradisiaca* L. var. *sapientum* Kuntze	Norfolk Is.	„

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